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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 125.

A. C. TRUE, Director.

A DIGEST

OF

RECENT EXPERIMENTS ON HORSE FEEDING.

BY

C. F. LANGWORTHY, Ph. D.,
Office of Experiment Stations.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., January 29, 1903.

Sir: I have the honor to transmit herewith a bulletin prepared by C. F. Langworthy, Ph. D., of the Office of Experiment Stations, which summarizes and discusses the results of experiments on the feeding and care of horses, and especially the investigations of recent years. The attempt has been made to include all the work which has been carried on at the experiment stations in the United States as well as some of the more important foreign investigations. Statistics were also gathered regarding the rations fed horses used by express companies, cab companies, fire departments, packing houses, breweries, etc., in different regions of the United States, with a view to learning the nutrients supplied to horses performing different amounts of work. The data have been compared with similar values for horses fed at a number of the experiment stations under more or less definitely known conditions. The rations fed army horses in this and other countries, the horses of French and other cab companies, etc., have also been included for purposes of comparison.

Thanks are due to Director W. A. Henry of the Wisconsin Station, Director H. J. Patterson of the Maryland Station, and Mr. G. M. Rommel of the Bureau of Animal Industry of this Department, for valuable suggestions, and to Mr. H. A. Pratt of the Department of the Interior, for assistance in making the calculations involved in preparing the material.

Believing that the bulletin will prove a useful summary of the information at present available regarding the feeding of horses, I recommend that it be published as Bulletin No. 125 of this Office.

Respectfully,
A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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RECENT EXPERIMENTS IN HORSE FEEDING.

INTRODUCTION.

The scientific study of different problems connected with the feeding of farm animals has been followed for something over half a century. Some of the very early work was with horses, but more generally it was carried on with other domestic animals. Within the last few years this phase of the problem has received much more attention, and feeding tests, digestion experiments, and more complicated investigations have accumulated in considerable numbers. The bulk of this work has been carried on in France and Germany; a creditable amount, however, has been done in this country, notably by the agricultural experiment stations, and the results of these experiments and observations have been published from time to time, and are very useful. Mention must be made also of the work of practical feeders, which is of great value.

In the present bulletin the attempt is made to bring together some of the more important results and deductions which may be gathered from the American and foreign experimental work, especially that of recent years. It is not the purpose to provide practical feeders with directions for feeding according to a particular formula; indeed this is not necessary, if it were possible, for practical feeders understand the needs of their horses and how to meet them. The object is rather to summarize matter which seems interesting and valuable, and which in many cases may give the reason for something of which the wisdom has long been recognized in practice.

In addition to the bulletins, reports, and other works cited in the following pages, a large number of scientific and popular journals, treatises on horse feeding, and similar publications have been consulted, as well as reports issued by American and foreign experiment stations.

That a scientific study of the feeding of horses may not be without direct practical value is shown by the work of Grandeau, Leclerc, Lavalard, and others for the Paris Cab and 'Bus companies. By means of experimental studies of the food value and digestibility of different feeding stuffs, carried on under definite conditions, it was possible to so modify the ration fed to the thousands of horses belonging to one of these companies that an annual saving of 1,000,000 francs or over was effected, while at the same time the health and strength of the horses were maintained at the usual standard. This was accomplished in the instance cited by demonstrating the value of Indian corn, against which there was a prejudice in France, and substituting it in part for oats.

The returns from scientific studies are not always so immediate, but the results are usually of use when the experiments have been well planned and carried out.

The problem of horse feeding is one which each feeder solves more or less for himself, the opinion regarding what is and what is not satisfactory feed varying more or less with the time and place. Opinions may differ as to the value of this food or that, but it is evident that the actual food requirements of a horse performing a given amount of work can not vary as a result of a change of opinion on the feeder's part. With horses, as with all animals, including man, the real problem is to supply sufficient nutritive material for building and repairing the body and furnishing it with the energy necessary for performing work, whether it be that which goes on inside the body (the beating of the heart, respiratory movements, etc.), or the work which is performed outside the body (hauling a load, etc.). The body temperature must also be maintained at the expense of the fuel ingredients, but whether material is burned in the body primarily for this purpose, or whether the necessary heat is a resultant of the internal muscular work, is not known with certainty.

The problem of successfully feeding horses differs somewhat from that encountered in feeding most domestic animals. Cattle, sheep, and pigs are fed to induce gains in weight, i. e., to fatten them, or in the case of milch cows to produce gains in the form of a body secretion (milk) rather than as fat in the body. In a similar way sheep are fed for the production of wool, and poultry for the production of eggs. Sometimes cattle are also fed as beasts of burden. Horses are fed almost universally as beasts of burden, whether the work consists in carrying a rider or drawing a load.

Mares with foal require food for the development of their young, and after birth the colt needs it for the growth and development of the body as well as for maintenance. Such demands for nutritive material are common to all classes of animals. Sometimes horses are fed to increase their weight; that is, to improve their condition. For instance, animals are often fattened by horse dealers before they are sold. However, generally speaking, the problem in horse feeding is to supply sufficient nutritive material for the production of the work required and at the same time to maintain the body weight. The almost universal experience of practical horse feeders, and the results of many carefully planned experiments, agree that there is no surer test of the fitness of any given ration than that it enables the horse fed to maintain a constant weight. If the animal loses weight it is evident that the ration is insufficient, while if gains in weight are made and the animal becomes fat it is evident that more feed is given than is necessary. Provided the horse is in good condition, it is seldom desirable to induce any considerable gain in weight. Reference is not made to the small daily fluctuations in weight, but to gains or losses which extend over a considerable period. The most satisfactory ration must necessarily be made up of materials which are wholesome and are relished by the horse. It should also be reasonable in cost. It must be abundant enough to meet all body requirements, but not so abundant that the horse lays on an undesirable amount of flesh.

PRINCIPLES OF NUTRITION.

The foundation principles of nutrition are the same in the case of all animals, including man. A brief discussion of the properties of food and the general laws of nutrition follows.

The study of foods and feeding stuffs has shown that although they differ so much in texture and appearance they are in reality made up of a small number of chemical constituents, namely, protein, fat, carbohydrates, and ash, together with a larger or smaller amount of water. The latter can be often seen, as in the juice of fresh plants. In dry hay no water or juice is visible. A small amount is, however, contained in minute particles in the plant tissues.

Protein is a name given to the total group of nitrogenous materials present. The group is made up mainly of the true proteids and albumens, such as the gluten of wheat, and of nitrogenous materials such as amids, which are believed to have a lower feeding value than the albumens.

The group "fat" includes the true vegetable fats and oils, like the oil in cotton seed or corn, as well as vegetable wax, some chlorophyl (the green coloring matter in leaves, etc.), and other coloring matters; in brief, all the materials which are extracted by ether in the usual laboratory method of estimating fat. The name "ether extract" is often and very properly applied to this group. Chemically considered, the true fats are glycerids of the fatty acids, chiefly oleic, stearic, and palmitic.

The group "carbohydrates" includes starches, sugars, crude fiber, cellulose, pentosans, and other bodies of a similar chemical structure. This group is usually subdivided, according to the analytical methods followed in estimating it, into "nitrogen-free extract" and "crude fiber;" the former subdivision including principally sugar, starches, and most of the pentosans, and the latter cellulose, lignin, and other woody substances which very largely make up the rigid structure of plants.

The proteids contain nitrogen in addition to carbon, oxygen, hydrogen, and a little phosphorus and sulphur. The fats consist of carbon, oxygen, and hydrogen, as do also carbohydrates. In the carbohydrates, however, the oxygen and hydrogen are always present in the proportions in which they occur in water, namely, two atoms of hydrogen to one of oxygen.

The group "mineral matter" includes the inorganic bodies present in the form of salts in the juices and tissue of the different feeding stuffs, the principal chemical elements found being sodium, potassium, calcium, chlorin, fluorin, phosphorus, and sulphur. The term "ash" is often and very properly used for this group, since the mineral matter represents the incombustible portion which remains when any given feeding stuff is burned.

As noted above, the functions of food are (1) to supply material to build and repair the body, and (2) to yield energy. The chemical composition of a feeding stuff serves as a basis for judging of its value for building and repairing body tissue. Its value as a source of energy must, however, be learned in another way. The most usual way of measuring energy is in terms of heat, the calorie being taken as a unit. This is the amount of heat which would raise the temperature of 1 kilogram of water 1° C., or 1 pound of water 4° F. Instead of this the unit of mechanical energy, the foot-ton (the force which would lift 1 ton 1 foot) may be used, but it is not as convenient. One calorie corresponds very nearly to 1.54 foot-tons. The heat of combustion of foods and feeding stuffs is ordinarily determined with the bomb calorimeter or other suitable devices. The fuel value of any food is equal to its heat of combustion less the energy of the excretory products derived from it and may be learned by taking into account the chemical composition of the food or feeding stuff, the proportions of the nutrients actually digested and oxidized in the body, and the proportion of the whole latent energy of each which becomes active and useful to the body for warmth and work. However, the fuel value may be and often is calculated from the composition of the food material supplied, since it has been found that 1 gram of protein furnishes 4.1 calories, 1 gram fat 9.3 calories, and 1 gram carbohydrates 4.1 calories, or 1 pound protein 1,860 calories, 1 pound fat 4,220 calories, and 1 pound carbohydrates 1,860 calories.[a]

The relation between the quantities of nitrogenous and nitrogen-free nutrients in the ration is called the nutritive or nutrient ratio. In calculating this ratio 1 pound of fat is taken as equivalent to 2.25 pounds of carbohydrates—this being approximately the ratio of their fuel values—so that the nutritive ratio is actually that of the protein to the carbohydrates plus 2.25 times the fat.

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[a] These values, which have been often used in the past, are known to be unsatisfactory, but are retained because better and more generally accepted data, obtained in experiments with animals, are not available.

In discussions relating to human food later and more accurate values have been proposed, namely, 1,820 calories per pound for protein and carbohydrates and 4,040 calories per pound for fats.

The body is necessarily made up of the same chemical elements as occur in food. Nitrogen is the characteristic element of body tissue and fluids. Carbon, oxygen, and hydrogen are also present, as well as the elements making up the various mineral matters of the body. Protein is the only nutrient which contains nitrogen, therefore this nutrient is essential for building and repairing body tissues. The carbon, oxygen, and hydrogen may be supplied theoretically by protein, fat, or carbohydrates; but a well-balanced diet or ration contains all in proper proportion. Protein, fat, and carbohydrates may be burned with the formation of carbon dioxid and water, and therefore all may serve as sources of energy.

The mineral matter in food is required for a number of different purposes, a considerable amount being needed for the formation of the skeleton. Some is also present in the organs and tissues. It can not, however, be regarded as a source of energy, according to commonly accepted theories, since it can not be burned with the formation of carbon dioxid and water. The water present in food is not a nutrient in the sense that it serves for building tissue or yielding energy, but it is essential, serving to carry the food in the digestive processes, to dilute the blood, and for many other physiological purposes. The oxygen of the air is required by all living animals for the combustion, or oxidation, of the fuel constituents of food.

When foods are burned in the body, i. e., oxidized, they give up the latent energy present in them. In determining the fuel value of protein, due allowance is made for the fact that combustion is not as complete in the body as in a furnace. In the latter, practically all organic materials are burned to carbon dioxid, water, and nitrogen; in the body, to carbon dioxid, water, and some cleavage product containing nitrogen, such as urea, uric acid, hippuric acid, and similar bodies which require further combustion before the free nitrogen is liberated. Combustion in a furnace and combustion in the body do not appear to be at all similar, but, generally speaking, they are the same from a chemical standpoint. The former takes place rapidly with the evolution of heat, and usually of light; the latter, more slowly and inconspicuously. If food is likened to fuel and the body to a furnace, the respiratory products given off from the lungs correspond to the combustion products which pass out through the flue. Ashes, in so far as they consist of material which will not burn (sand, bits of rock, etc.), and bits of coal which do not burn because they fall through the grate, or for some similar reason escape combustion, represent the feces (the indigestible and accidentally undigested material derived from the food). The bits of coal found in the ashes which are partially burned, but still contain some material valuable as fuel, correspond to the urea and other incompletely oxidized nitrogenous bodies excreted in the urine. There is this difference, however, the furnace would have completed the combustion of the partly burned bits of coal if they had not been shaken out with the ashes, while the body can not burn the urea more completely. The body differs from a machine in a number of important ways; for instance, it is itself built up of the same materials which it utilizes as fuel, and further, if an excess of fuel, i. e., food, is supplied, it may be stored as a reserve material for future use, generally in the form of fat or glycogen.

The amount of work performed by a horse, for convenience in measurement, may be resolved into several factors, as follows: (1) The energy expended in chewing, swallowing, and digesting food, keeping up the beating of the heart, circulation of the blood, respiratory movements, and other vital processes;[a] (2) the energy which is expended in moving the body, walking, trotting, etc., which is usually spoken of as energy required for forward progression; and (3) the energy which is expended in carrying a rider, as in the case of a saddle horse, or drawing a load, as in the case of a draft animal or carriage horse.

The character of the road, whether level or up or down hill, is an important factor in determining the amount of work. It is evident that more energy is required to lift the body at each step and move it forward when climbing an incline than when walking on a level. In the same way, when a load is drawn uphill it must be raised as well as drawn forward.

Work may be measured as foot-pounds or foot-tons, or by any other convenient unit. A foot-pound is the amount of energy expended in raising 1 pound 1 foot; a foot-ton, that expended in raising 1 ton 1 foot; a commonly used unit of force is the "ton power," equivalent to 550 foot-pounds per second. Work may also be measured in terms of heat, i. e., calories. This is especially convenient in discussing problems of nutrition, since the heat of combustion is one of the factors usually determined or calculated when foods are analyzed; and furthermore, the feeding standards which have been proposed for horses and other farm animals show the requirements per day in terms of nutrients and energy. One calorie corresponds, as stated above, very nearly to 1.54 foot-tons.

COMPOSITION OF FEEDING STUFFS.

The feeding stuffs of most importance for horses are cereal grains, such as oats and corn, either ground or unground; leguminous seeds, as beans and peas; cakes, and other commercial by-products, as oil-cake, gluten feed, and so on; fodder crops, green or cured; and different roots, tubers, and green vegetables. In quite recent times cane molasses, beet molasses, and other beet-sugar by-products, have assumed more or less importance in this connection. The composition of a number of these different feeding stuffs may be seen by reference to the table below, which shows the average composition as determined by analysis, and when possible the digestible nutrients furnished for horses by each 100 pounds of the feeding stuffs, the latter data having been calculated, as explained elsewhere (p. 40), by the aid of figures obtained in digestion experiments with horses. In a number of cases such calculations have not been made, for the reason that experiments showing the digestibility of feeding stuffs had not been found, nor were results of experiments made with similar feeding stuffs available. The comparatively large number of feeding stuffs of which the digestibility has not been determined indicates one of the lines of work which might be profitably followed.

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[a] The heat of the body is closely connected with this kind of work, and may be derived either from the combustion of material directly for that purpose, or may be the result of the energy liberated when internal muscular work is performed, or may be due to both causes acting together.

TABLE 1.—*Average composition of a number of feeding stuffs.*

Kind of food material.	Percentage composition.						Digestible materials in 100 pounds.				Energy in 100 lbs. digestible nutrients.
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
GREEN FODDER.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
Corn fodder	79.3	1.8	0.5	12.2	5.0	1.2	......	......	......	......	......
Corn leaves and husks	66.2	2.1	1.1	19.0	8.7	2.9	......	......	......	......	......
Cornstalks stripped	76.1	.5	.5	14.9	7.3	.7	......	......	......	......	......
Kafir corn	73.0	2.3	.7	15.1	6.9	2.0	......	......	......	......	......
Rye fodder	76.6	2.6	.6	6.8	11.6	1.8	......	......	......	......	......
Oat fodder	62.2	3.4	1.4	19.3	11.2	2.5	......	......	......	......	......
Wheat fodder	77.3	2.3	.7	12.0	5.9	1.8	......	......	......	......	......
Redtop in bloom	65.3	2.8	.9	17.7	11.0	2.3	......	......	......	......	......
Tall oat grass in bloom	69.5	2.4	.9	15.8	9.4	2.0	......	......	......	......	......
Orchard grass in bloom	73.0	2.6	.9	13.3	8.2	2.0	......	......	......	......	......
Meadow fescue in bloom	69.9	2.4	.8	14.3	10.8	1.8	......	......	......	......	......
Italian rye grass coming into bloom	73.2	3.1	1.3	13.1	6.8	2.5	......	......	......	......	......
Timothy at different stages	61.6	3.1	1.2	20.2	11.8	2.1	......	......	......	......	......
Kentucky blue grass at different stages	65.1	4.1	1.3	17.6	9.1	2.8	......	......	......	......	......
Hungarian grass	71.1	3.1	.7	14.2	9.2	1.7	......	......	......	......	......
Red clover at different stages	70.8	4.4	1.1	13.5	8.1	2.1	3.44	......	10.91	3.79	33,796
Alsike clover in bloom[a]	74.8	3.9	.9	11.0	7.4	2.0	3.05	......	8.91	3.46	28,681
Crimson clover[a]	80.9	3.1	.7	8.4	5.2	1.7	2.42	......	6.80	2.43	21,669
Alfalfa at different stages	71.8	4.8	1.0	12.3	7.4	2.7	3.75	......	9.96	3.46	31,936
Cowpea	83.6	2.4	.4	7.1	4.8	1.7	......	......	......	......	......
Soy bean	75.1	4.0	1.0	10.6	6.7	2.6	......	......	......	......	......
SILAGE.											
Corn silage	74.4	2.2	1.1	15.0	5.8	1.5	......	......	......	......	......
Sorghum silage	76.1	.8	.3	15.3	6.4	1.1	......	......	......	......	......
Red-clover silage	72.0	4.2	1.2	11.6	8.4	2.6	......	......	......	......	......
Soy-bean silage	74.2	4.1	2.2	7.0	9.7	2.8	......	......	......	......	......
Cowpea-vine silage	79.3	2.7	1.5	7.6	6.0	2.9	......	......	......	......	......

[a] Digestibility calculated from values obtained with green alfalfa.

TABLE 1.—*Average composition of a number of feeding stuffs*—Continued.

Kind of food material.	Percentage composition.						Digestible materials in 100 pounds.				Energy in 100 lbs. digestible nutrients.
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
HAY AND DRY COARSE FODDER.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
Corn fodder, field cured	42.2	4.5	1.6	34.7	14.3	2.7	......	......	......	......	......
Corn leaves, field cured	30.0	6.0	1.4	35.7	21.4	5.5	......	......	......	......	......
Corn husks, field cured	50.9	2.5	.7	28.3	15.8	1.8	......	......	......	......	......
Cornstalks, field cured	68.4	1.9	.5	17.0	11.0	1.2	......	......	......	......	......
Corn stover, field cured	40.5	3.8	1.1	31.5	19.7	3.4	......	......	......	......	......
Kafir-corn stover, field cured	19.2	4.8	1.6	39.6	26.8	8.0	......	......	......	......	......
Barley hay	10.6	9.3	2.5	48.7	23.6	5.3	......	......	......	......	......
Oat hay	16.0	7.4	2.7	40.6	27.2	6.1	......	......	......	......	......
Wheat hay	8.8	6.0	1.8	55.3	22.5	5.6	......	......	......	......	......
Redtop cut at different stages[a]	8.9	7.9	1.9	47.5	28.6	5.2	4.51	0.39	26.93	11.35	81,234
Redtop cut in bloom[a]	8.7	8.0	2.1	46.4	29.9	4.9	4.57	.43	26.31	11.87	81,330
Orchard grass[a]	9.9	8.1	2.6	41.0	32.4	6.0	4.62	.54	23.25	12.86	78,036
Timothy	13.2	5.9	2.5	45.0	29.0	4.4	1.25	1.18	21.29	12.35	69,873
Kentucky blue grass[a]	21.2	7.8	3.9	37.8	23.0	6.3	4.45	.81	21.43	9.13	68,536
Hungarian grass[a]	7.7	7.5	2.1	49.0	27.7	6.0	4.28	.43	27.78	11.00	81,905
Meadow fescue[a]	20.0	7.0	2.7	38.4	25.0	6.9	4.00	.56	21.77	10.28	69,415
Italian rye grass[a]	8.5	7.5	1.7	44.9	30.5	6.9	4.28	.35	25.51	12.11	79,410
Mixed grasses[a]	15.3	7.4	2.5	42.1	27.2	5.5	4.23	.52	23.87	10.80	74,554
Rowen (mixed)[a]	16.6	11.6	3.1	39.4	22.5	6.8	6.62	.64	22.34	8.93	73,175
Mixed grasses and clovers[a]	12.9	10.1	2.6	41.3	27.6	5.5	5.77	.54	23.42	10.96	76,957
Swamp hay[a]	11.6	7.2	2.0	45.9	26.6	6.7	4.11	.41	26.02	10.56	77,413
Salt-marsh hay	10.4	5.5	2.4	44.0	30.0	7.7	......	......	......	......	......
Red clover	15.3	12.3	3.3	38.1	24.8	6.2	6.85	.95	24.19	9.27	78,984
Red clover in bloom[b]	20.8	12.4	4.5	33.8	21.9	6.6	6.91	1.29	21.46	8.19	73,450
Alsike clover[b]	9.7	12.8	2.9	40.7	25.6	8.3	7.13	.83	25.84	9.57	82,630
White clover[b]	9.7	15.7	2.9	39.3	24.1	8.3	8.74	.83	24.96	9.01	82,942
Crimson clover[b]	9.6	15.2	2.8	36.6	27.2	8.6	8.47	.80	23.24	10.17	81,272
Alfalfa	8.4	14.3	2.2	42.7	25.0	7.4	10.67	.42	29.98	9.75	95,520
Cowpea	10.7	16.6	2.9	42.2	20.1	7.5	......	......	......	......	......
Soy bean	11.3	15.4	5.2	38.6	22.3	7.2	......	......	......	......	......
Flat pea	8.4	22.9	3.2	31.4	26.2	7.9	......	......	......	......	......
Soy-bean straw	10.1	4.6	1.7	37.4	40.4	5.8	......	......	......	......	......
Wheat straw	9.6	3.4	1.3	43.4	38.1	4.2	.91	.85	12.20	6.74	40,544
Rye straw[c]	7.1	3.0	1.2	46.6	38.9	3.2	.83	.79	13.10	6.89	42,020
Oat straw[c]	9.2	4.0	2.3	42.4	37.0	5.1	1.11	1.51	11.91	6.55	42,770
Buckwheat straw	9.9	5.2	1.3	35.1	43.0	5.5	......	......	......	......	......
ROOTS AND TUBERS.											
Potatoes	78.9	2.1	.1	17.3	.6	1.0	1.85	......	17.20	.05	35,525
Carrots	88.6	1.1	.4	7.6	1.3	1.0	1.09	......	7.13	......	15,290
GRAINS AND OTHER SEEDS.											
Corn, dent	10.6	10.3	5.0	70.4	2.2	1.5	5.95	2.39	62.09	......	136,636
Corn, flint	11.3	10.5	5.0	70.1	1.7	1.4	6.07	2.39	61.83	......	136,376
Corn, all varieties	10.9	10.5	5.4	69.6	2.1	1.5	6.07	2.58	61.39	......	136,363
Kafir corn	12.5	10.9	2.9	70.5	1.9	1.3	......	......	......	......	......
Chicken corn	14.8	10.6	2.6	58.8	8.7	4.5	......	......	......	......	......
Barley	10.9	12.4	1.8	69.8	2.7	2.4	......	......	......	......	......
Oats	11.0	11.8	5.0	59.7	9.5	3.0	9.39	3.60	45.25	2.82	122,062
Rye	11.6	10.6	1.7	72.5	1.7	1.9	8.51	.72	63.29	1.70	139,747
Wheat, all varieties	10.5	11.9	2.1	71.9	1.8	1.8	......	......	......	......	......
Cotton seed, whole, with hulls	9.1	19.6	20.1	28.3	18.9	4.0	......	......	......	......	......
Cowpea	11.9	23.5	1.7	55.7	3.8	3.4	......	......	......	......	......
MILL PRODUCTS.											
Corn meal	15.0	9.2	3.8	68.9	1.9	1.4	6.99	2.55	64.70	.38	144,454
Oats, ground	11.7	11.0	3.9	52.3	18.0	3.1	9.06	3.12	45.03	2.59	118,727
Corn and cob meal	15.1	8.5	3.5	64.8	6.6	1.5	......	......	......	......	......
Barley meal	11.9	10.5	2.2	66.3	6.5	2.6	......	......	......	......	......

[a] Digestibility calculated from values obtained with meadow hay.
[b] Digestibility calculated from values obtained with red clover hay.
[c] Digestibility calculated from values obtained with wheat straw.

TABLE 1.—*Average composition of a number of feeding stuffs*—Continued.

Kind of food material.	Percentage composition.						Digestible materials in 100 pounds.				Energy in 100 lbs. digestible nutrients.
	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
MILL PRODUCTS—con.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
Rye flour	13.1	6.7	0.8	78.3	0.4	0.7	......	......	......	......	......
Pea meal	10.5	20.2	1.2	51.1	14.4	2.6	......	......	......	......	......
Ground corn and oats (equal parts)	11.9	9.6	4.4	71.9		2.2	......	......	......	......	......
WASTE PRODUCTS.											
Corncob	10.7	2.4	.5	54.9	30.1	1.4	......	......	......	......	......
Hominy chop	11.1	9.8	8.3	64.5	3.8	2.5	......	......	......	......	......
Corn bran	8.7	9.8	6.2	62.6	11.2	1.5	......	......	......	......	......
Gluten meal	8.6	30.0	8.8	49.2	2.6	.8	......	......	......	......	......
Gluten feed	7.8	23.4	8.3	53.2	6.2	1.1	......	......	......	......	......
Oat feed	7.7	16.0	7.1	59.4	6.1	3.7	......	......	......	......	......
Barley screenings	12.2	12.3	2.8	61.8	7.3	3.6	......	......	......	......	......
Brewers' grains, wet	75.7	5.4	1.6	12.5	3.8	1.0	......	......	......	......	......
Brewers' grains, dried	8.0	24.1	6.7	44.8	13.0	3.4	......	......	......	......	......
Rye bran	11.8	14.7	2.8	63.9	3.3	3.5	......	......	......	......	......
Wheat bran	11.9	15.4	4.0	53.9	9.0	5.8	......	......	......	......	......
Wheat middlings	12.1	15.6	4.0	60.4	4.6	3.3	......	......	......	......	......
Wheat shorts	11.8	14.9	4.5	56.8	7.4	4.6	......	......	......	......	......
Wheat screenings	11.6	12.5	3.0	65.1	4.9	2.9	......	......	......	......	......
Cotton-seed meal	8.2	42.3	13.1	23.6	5.6	7.2	......	......	......	......	......
Cotton-seed hulls	11.1	4.2	2.2	33.4	46.3	2.8	......	......	......	......	......
Linseed meal, old process	9.2	32.9	7.9	35.4	8.9	5.7	......	......	......	......	......
Linseed meal, new process	9.9	35.9	3.0	36.8	8.8	5.6	......	......	......	......	......
Beet-sugar molasses	25.7	[a] 7.3	......	[b] 58.2	......	8.8	7.3	......	58.2	......	259,182
Cane-sugar molasses	25.1	[a] 2.4	......	[b] 69.3	......	3.2	3.2	......	69.3	......	298,398

[a] Largely nonalbuminoid nitrogenous materials.
[b] Very largely sugars.

COMPARATIVE VALUE OF FEEDING STUFFS.

CEREAL GRAINS.

It will be seen that the cereal grains resemble each other quite closely in composition, being characterized by fairly low water content and a considerable amount of protein and nitrogen-free extract. Some crude fiber, derived from the outer or bran layer of the corn, is also present. The superiority of one grain over another must therefore depend, in large measure, if it exists at all, on some factor other than composition. It has been urged by many that oats possess a peculiar stimulating body called "avenin," and are on this account superior to other grains for horses. Oats undoubtedly possess a flavor or some such characteristic which makes them a favorite food with horses, but the most careful chemical study has failed to reveal any substance of the nature of the theoretical avenin. Recent experiments[a] have shown that the fat of oats and oat straw is more thoroughly digested than that of other cereals. This is suggested as a possible explanation of the superior feeding value of oats.

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[a] Landw. Jahrb., 29 (1900), p. 483.

It is believed by many that horses show more spirit when oats form part of the ration. Discussing this subject, Director W. A. Henry,[a] of the Wisconsin Experiment Station, says:

> Horses nurtured on oats show mettle which can not be reached by the use of any other feeding stuff. Then, too, there is no grain so safe for horse feeeding, the animal rarely being seriously injured if by accident or otherwise the groom deals out an oversupply. This safety is due in no small measure to the presence of the oat hull, which causes a given weight of grain to possess considerable volume, because of which there is less liability of mistake in measuring out the ration; further, the digestive tract can not hold a quantity of oat grains sufficient to produce serious disorders. Unless the horse is hard pressed for time or has poor teeth oats should be fed in the whole condition. Musty oats should be avoided.
>
> Horsemen generally agree that new oats should not be used, though Boussingault, conducting extensive experiments with army horses, arrived at the conclusion that new oats do not possess the injurious qualities attributed to them.

In the opinion of Lavalard:[b]

> Not only may single grains and other single foods be substituted for oats, but more or less complex mixtures may be used as well. We believe that both from a hygienic and an economic standpoint our experiments have settled this matter, which has provoked so much discussion. An examination of the statistics we have gathered in the last thirty-five years show that, although a great saving has been effected, it has not been at the expense of the productive power of the horses.

Boussingault, perhaps, first suggested on the basis of experiments that other materials may be substituted for oats in the ration of horses. He prepared a table of nutritive equivalents, using hay as a unit of comparison. This was not very satisfactory, since the composition of hay varies within wide limits.

The grain most commonly substituted for oats in this country is Indian corn or maize. It is so commonly used, especially in the South and West, that it is difficult to realize the prejudice which has existed against it in other countries. It has been asserted that there are climatic and other conditions which render corn a suitable horse feed in America which do not exist elsewhere. This hardly seems reasonable, and has not been borne out by the numerous experiments undertaken in France, Germany, and other countries. Such experiments have demonstrated the value of corn and shown the truth of the opinions generally held in this country, namely, that it is a safe and satisfactory feeding stuff for horses.

Barley, rye, and wheat are sometimes fed to horses. Their resemblance to oats will be seen by reference to the table. All these grains should be substituted on the basis of chemical composition, and not pound for pound. As would be expected, the ground grains differ little from the same varieties before grinding.

Bran, shorts, middlings, and other by-products vary in composition, but all have a low water content, while the crude fiber content is generally rather high. Their nutritive ingredients are principally protein and carbohydrates. The high crude fiber content is due to the fact that these products represent the outer layers of the grain, which are more hard and firm in construction than the interior portion, which consists largely of starch.

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[a] Feeds and Feeding, Madison, Wis., 1898.

[b] Experiment Station Record, 12 (1900-1901), p. 4.

The total number of tests to compare different feeding stuffs for horses which have been undertaken by the agricultural experiment stations in the United States is not large compared with the tests made with other farm animals. The results obtained are, however, interesting. Some of those which have to do with grain, whole and ground, follow:

At the Maine Station Jordan[a] made a comparison with oats and a mixture of one-third pea meal and two-thirds middlings for Percheron colts. No advantage was observed for the oats over the mixture. A comparison of oats with mixed grains (middlings, gluten meal, and linseed meal), also made with colts, showed that considerably larger gains were made on the mixed grain ration, which was also the more nitrogenous.

At the Utah Station J. W. Sanborn[b] tested the effect of feeding grains (rye, oats, and bran) and cut hay, mixed and separately. So far as the test showed, the two methods of feeding were equally satisfactory. No regular variation in the weight of the two lots of horses was observed when the comparative value of the whole and cut hay (alfalfa and clover mixed) was tested.

The comparative value of corn and oats supplementing bran and hay was also tested at the Utah Station.[c] The grains were ground and mixed before feeding. In these and other tests referred to above it appears that during the summer corn and timothy were not as good as oats, wheat, and clover for maintaining horses. During the winter corn and timothy were as satisfactory as oats, clover, and timothy in maintaining weight. During the spring and summer wheat or bran and mixed hay produced greater gains in weight than oats, wheat, or bran and mixed hay. In another trial[d] corn meal and timothy hay did not sustain work horses as well as oats, wheat, and clover hay.

The value of oats versus bran and shorts, the feeding value of wheat, wheat versus bran and ground wheat, were tested with horses and mules by J. H. Shepperd[e] at the North Dakota Station. Bran and shorts were found to have practically the same feeding value as oats. Unground wheat was poorly digested, and it was therefore believed undesirable to feed it as a sole grain ration. When wheat was added to a ration of bran and shorts 1:1 no advantage was gained. On the basis of tests reported, bran and ground wheat 1:2 was considered a more satisfactory grain ration for horses at light work than whole oats.

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[a] Maine Station Rpt. 1890, p. 68.

[b] Utah Station Bul. 13.

[c] Utah Station Bul. 36.

[d] Utah Station Rpt. 1892, p. 30.

[e] North Dakota Station Bul. 20.

The New Hampshire Station[a] studied the value of different grain mixtures for horses with the view to determining whether the cost of a ration could not be diminished by lessening the amount of oats fed. The rations consisted of different mixtures of oats, bran, corn, gluten feed, linseed-oil meal, and cotton-seed meal. Fairly good results were obtained with all the grain mixtures, the mixture containing cotton-seed meal being least satisfactory, as it was not relished at first by the horses. It is stated by C. W. Burkett, who carried on the tests, that the oats proved no more satisfactory than the other concentrated feeding stuffs, either in respect to the general condition of the animal or the efficiency for work, and the conclusion was drawn that a combination of feeding stuffs, furnishing the desired nutriment at a reasonable cost, should be considered in preparing rations for horses. A mixture of bran and corn, half and half, is regarded as a good substitute for corn and oats for work horses.

In a study of alfalfa hay and timothy hay for horses at the Utah Station[b] the comparative merits of oats and a mixture of bran and shorts were also tested. The conclusion was drawn that the mixed grain could be satisfactorily substituted for oats.

The barley grown on the Pacific coast is extensively used in the feeding of horses, and its use for this purpose is old in other countries. Elsewhere barley is not extensively used as a feed in the United States, doubtless owing to the fact that it is in such demand for brewing purposes that it is usually high in price. Wherever it is grown, however, it is frequently possible to secure at a low cost grain which is off color owing to rain or fog during harvest, and which, for this or some other reason, is unfit for brewing, but valuable as feed.

Barley may be fed whole to horses having good teeth and not required to do severe work. Since ground barley, like wheat, forms a pasty mass when mixed with saliva it is regarded as more satisfactory to crush than to grind it, if for any reason it is considered undesirable to feed the grain whole.

At the North Dakota Station J. H. Shepperd[c] has recently studied the value of barley as a feed for work horses and mules. For some months this grain was fed with timothy hay to three horses and two mules. The mules did not eat the barley with marked relish at any time, but for two months, during which time they were performing light work, they ate enough to keep them in condition. The work was then increased, but they would not eat a correspondingly greater quantity of barley, and soon began to refuse it altogether for a day or so at a time. The mules were then given oats on alternate months. This grain was eaten with relish, and gains in weight were made. Although the trial lasted nine months, the mules persistently refused barley.

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[a] New Hampshire Station Bul. 82.

[b] Utah Station Bul. 77.

[c] North Dakota Station Bul. 45.

Of the horses mentioned above, two were work horses. They were fed alternately barley and oats with timothy hay for nine periods of twenty-eight days each. They ate the barley without regard to the amount of work required of them. On the oat ration there was an average daily gain of 0.38 pound per horse. On the barley ration there was an average daily gain per horse of 0.15 pound. In both cases the horses averaged 5.50 hours' work per day.

This trial indicates that horses, when taxed to the limit by hard work, can not be supported upon barley quite so well as upon oats, and that it is worth slightly less per pound than oats with stock which is given a medium amount of work. It indicates further that mules take less kindly to barley than do horses, and that horses which are inclined to be "dainty" will not eat barley so readily as oats.

Malted barley was compared with oats in a trial made with four work horses. The two grains were alternated in different periods. Oat hay was supplied as coarse fodder. The malted barley was prepared as follows: After soaking in water for twenty-four hours the grain was spread on the floor in a layer 6 inches or less in depth and allowed to remain until the sprouts were 0.5 to 0.75 inch long; it was then fed. On the oat ration there was a daily gain of 0.49 pound, and on the malted barley there was an average daily loss of 0.76 pound per horse. When fed malted barley the horses ate 0.1 pound more grain than when fed oats. In this test the horses worked between five and six hours per day on an average.

A mixture of malted barley and bran was also compared with oats, the two rations being alternated as above. The grains were mixed in the proportion of two parts of barley (before malting) to one part of bran. As in the above test, oat hay was fed with the grain. The horses worked some seven hours per day. When fed a barley and bran ration they ate an amount equivalent to about 17.4 pounds of dry grain per day. There was an average daily loss of 0.8 pound per horse. When fed the oat ration an average of 16.2 pounds was consumed per day, and there was an average daily gain per horse of 0.22 pound. In other words, the horses did not maintain their weight on the bran and malted barley, although they ate a larger quantity than when the oat ration was fed.

These trials indicate that malted barley is not an economical feed for work horses, and that the addition of 1 part bran to 2 parts of malt, as measured by the dry barley, from which it was produced, is neither a cheap nor satisfactory feed for hard-worked horses.

Few experiments have been reported on the feeding value of Kafir corn for horses. At the Oklahoma Station, according to Morrow and

Bone,[a] 41 bushels of ground Kafir corn were fed during a year to a pair of work horses in addition to other grain and coarse fodder. From this test and others made with different farm animals the conclusion was drawn that Kafir corn is a healthful, palatable, and nutritious feed with a feeding value somewhat less than that of corn. This grain is very flinty, and to secure the best results should be ground. According to information recently received from the station, Kafir corn is highly esteemed locally as a feed for horses, many being kept throughout the year on this grain and prairie hay. The unthrashed heads are commonly fed, a head of Kafir corn being regarded as equivalent to an ear of corn.

At the Mississippi Station[b] chicken corn, a variety of Kafir corn, was compared with corn meal as a feed for mules doing heavy work, mixed hay being fed in addition to the grain ration. The mules fed the chicken corn lost in weight a little more than those fed corn meal. According to those making the test "the feeding value of the chicken corn is about as high as that of the corn."

LEGUMINOUS SEEDS.

Beans and other leguminous seed resemble the cereal grains in having a low water content. In Europe horse beans are common feeding stuff for horses. Lavalard says:[c]

> The experiments made many years ago for the Paris cab companies warrant the statement that when beans replace oats, only half the quantity should be used. Tests made with army horses have confirmed this conclusion. The chemical composition of beans shows why they are regarded as more nutritious than oats alone. Beans may be advantageously fed to horses required to perform long continued, sudden, or severe labor. The opinion is prevalent in England that in hunting it is always possible to recognize horses fed with beans by their great endurance. In accord with the practice of the leading racing stables, we used a large proportion of beans in the ration of young horses which were being trained. The results obtained were most satisfactory.

OIL CAKES AND OTHER COMMERCIAL BY-PRODUCTS.

The various cakes, gluten materials, and similar feeding stuffs are, generally speaking, commercial by-products. Thus, cotton-seed cake is the material left after the oil has been expressed from the cotton seed. In the same way, linseed cake is the residue obtained in the manufacture of linseed oil. If this cake is ground it becomes linseed meal. In the manufacture of beer the malted grain is known as brewers' grain and is best fed after drying. When starch is manufactured from corn, the nitrogenous portion of the grain is rejected and constitutes gluten feed and gluten meal. The cereal breakfast food companies have placed many feeding stuffs upon the market made up of various by-products obtained in the manufacture of their breakfast foods and similar products. These feeding stuffs vary in value, but may generally be said to represent the branny portion of the grains from which they are derived.

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[a] Oklahoma Station Rpt. 1899, p. 31.

[b] Mississippi Station Bul. 8.

[c] Loc. cit.

A comparison was made by E. B. and L. A. Voorhees[a] of dried brewers' grains when substituted for oats, pound for pound, at the New Jersey stations, eight horses heavily worked during the summer being used. As shown by weight and general condition of the animals, the brewers' grains were fully equal to the oats, pound for pound, while their cost was considerably less. In a second trial, dried brewers' grains were compared with a mixture of wheat bran and linseed meal 5 : 1.5 when fed in addition to timothy hay and corn. The uniformity in the amount of feed consumed and the weight of the animals, taken in connection with the work performed, indicates that there was no material difference in the value of the two rations. According to calculations made (timothy hay at the time being worth $18, wheat bran $17.50, corn meal $22, dried brewers' grain $17, and linseed meal $29 per ton), a farm horse weighing 1,000 pounds can be fed for $30.84 during the six months of the year when the most work is performed if dried brewers' grain furnishes the bulk of the necessary protein, and for $33.49 if wheat bran and linseed meal are the chief sources of this nutrient. If the fertilizing value of the feeding stuffs is taken into account the difference in favor of the brewers' grains is less marked.

In tests made by Emery[b] at the North Carolina Station horses were satisfactorily fed 2 pounds of cotton-seed meal per head daily as part of the mixed ration. When the amount was increased to 3.5 pounds the results were not as favorable. It is stated that neither of the horses used in the test showed any symptoms which indicated that cotton-seed meal disagreed with them. It is also stated that at the Biltmore estate 2 pounds of cotton-seed meal per head daily were fed to the horses and mules with 13 to 15 pounds of cut hay and finely cut corn feed, 4 pounds of wheat bran, and 6 pounds of corn meal. On Sundays the ration was made up of whole corn and oats and uncut hay. According to later information the feeding of cotton-seed meal has not been found satisfactory at Biltmore. In the tests with mixed rations, carried on at the New Hampshire Station (p. 18), the cotton-seed mixture was least satisfactory.

In the opinion of Director Stubbs,[c] of the Louisiana stations, cotton-seed meal may be fed with satisfactory results to horses and mules. At the Louisiana stations 1 or 2 pounds per mule per day have been fed with success. Six pounds is regarded as the maximum quantity which it is desirable to feed, and, in Director Stubbs's opinion, this amount should be led up to gradually. He notes that only bright yellow cotton-seed meal of a nutty, pleasant odor and taste should be used, and that no reddish or musty meal should be fed. It is stated that excessive quantities of cotton-seed meal should be avoided, since it is a very concentrated feed. It should be gradually added to a ration, carefully mixed with other feeds, until mules learn to relish it, and no uneaten residues should be allowed to ferment in the feed boxes.

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[a] New Jersey Stations Bul. 92, Rpt. 1893, p. 179.

[b] North Carolina Station Bul. 109.

[c] Louisiana Planter, 28 (1902), p. 178.

The cereal grains, ground and unground, commercial by-products, leguminous seeds, oil cakes, and similar products are very frequently called concentrated feeds, the name being suggested by the fact that, generally speaking, the food value, especially the protein content, is high in comparison with the bulk. So far as the general experience and the results of American and foreign feeding experiments go, most of the common feeding stuffs in the group are wholesome and valuable for horses. If any one of these feeding stuffs is substituted for oats, which may be taken for a standard, the substitution should be proportional to the composition of the two feeds and not pound for pound.

FORAGE CROPS, FRESH AND CURED.

The various forage crops—grass, clover, Kafir corn, corn, etc.—all have a high water content; that is, they are more or less succulent and juicy. They contain, however, considerable nutritive material, usually protein and carbohydrates, and are valuable feeding stuffs.

The leguminous forage crops—alfalfa, clover, cowpeas, soy beans, vetch, etc.—are richer in protein than the grasses. When the forage crops are dried and cured the resulting hay is richer in proportion to its bulk than the green material; in other words, it has been concentrated by the evaporation of the greater part of the water present. However, this is not the only change which has taken place. When hay is properly cured it undergoes a peculiar sort of fermentation or oxidation which materially affects its composition.

As shown by Holdefleis's[a] recent investigations, fermentation improves the hay by diminishing the quantity of crude fiber and by increasing the relative amount of other nutrients, especially nitrogen-free extract. The greater the fermentation the more the crude fiber is diminished, and this is especially marked when hay is dried on racks. Hay which has undergone proper fermentation has a better flavor and agrees better with animals and is apparently more digestible than hay which has dried quickly in the sun without fermentation. Fermentation apparently diminishes the amount of pentosans in hay, especially in the case of hay from grasses. It also seems that the relative amount of true protein is increased.

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[a] Mitt. Landw. Inst. Univ. Breslau, 1899, p. 59.

The feeding value of different forage crops, fresh and cured, depends in considerable degree upon the stage of growth, as has been shown by a number of chemical studies of the composition of different crops and cuttings of alfalfa, young and more matured corn forage, etc. Generally speaking, the nutritive value of the crop increases until growth is complete and diminishes somewhat as the plants mature or become overripe. Straw, the fully ripened stalk of cereal grains, contains some nutritive material, but is less nutritious than the same portion of the plant cut before ripening. In the perfectly ripe condition the nutritive material, elaborated in different portions of the ordinary forage plants, has been conveyed to the seed and used for its development or stored as reserve material.

Green forage crops are frequently preserved by ensiling. In this process the material undergoes a peculiar oxidation which correspondingly changes it in composition and food value. Some of the carbohydrates are changed into alcohol, acetic and other acids, and crude fiber is undoubtedly softened somewhat, and possibly the silage is thus rendered more digestible. Bodies having peculiar flavor and odor are also formed.

The green crops, hay, straw, other cured crops, and silage are frequently called "coarse fodder" or "roughage." This term is due to the fact that they contain a comparatively small amount of nutritive material and a high proportion of crude fiber as compared with their total bulk. Although inferior to concentrated feeds in composition, they are an essential part of the ration of horses and other farm animals, serving to give the required bulk to the food and being useful in other ways.

It is believed that unless the food, when taken into the stomach, is comparatively bulky and the mass is more or less loose in structure, it is not readily acted on by the digestive juices. The intestinal tract of the horse is long in proportion to the size of the animal, and food remains in it for several days. Experiments indicate that crude fiber, which is only slightly digestible by man, is quite thoroughly digested by horses, and even more thoroughly digested by ruminants, owing its digestibility to the fact that it is fermented for a comparatively long period by micro-organisms in the intestines.

Regarding the need of straw in a ration to supply the necessary bulk, Lavalard's[a] opinion follows:

> The statement is often made that horses can not do without straw [to supply coarse fodder]. This is an error, for we have fed horses hay and oats during very long periods, and have never noticed that they suffered any inconvenience or detriment. This is a matter of importance, since it is often inconvenient to obtain straw [even for bedding], and in such cases peat, sawdust, sand, etc., may be profitably used as bedding in place of straw.

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[a] Loc. cit.

This does not mean that crude fiber, one of the important constituents of coarse fodder, is not required, but rather that a sufficient amount of crude fiber was supplied by the hay and oats in the cases cited by the author. As part of a series comprising some fifteen experiments carried on at the Maryland Station,[a] an attempt was made to feed the horses on oats alone. At the beginning of the trial one horse consumed 6,000 grams (13.2 pounds) and the other 6,750 grams (14.9 pounds) of oats per day, but after a few days refused to eat. The experiment could not be continued long enough to permit the determination of the coefficients of digestibility. Under the experimental conditions it was regarded as impossible to maintain horses on a grain ration alone; it seemed certain that they required some coarse fodder in addition. From such experiments the general deduction is obvious that the common practice of feeding horses on a ration of grain and coarse fodder is reasonable and based on the actual physiological requirements of the animal.

A number of feeding experiments have been made on the comparative value for horses of different forage crops, fresh and cured. The American experiment stations have studied the more important coarse fodders in use in this country. A summary of their work follows.

D. O. Nourse[b] of the Virginia Station reported a number of trials of the value of corn silage for horses and mules. Gradually increasing amounts were fed until they were given all the silage they could eat, with hay and grain in addition. Provided animals are gradually accustomed to it, as shown by these tests, silage is a satisfactory feed for horses and mules.

In tests carried on by J. H. Shepperd[c] at the North Dakota Station oat straw and prairie hay were compared. Oat straw was found to be a cheaper horse fodder than hay, but when it was used more careful feeding was necessary to keep the horses in good condition. In a subsequent test[d] brome grass hay gave as good results when fed to work horses as timothy hay.

In a study of different grain mixtures for work horses, carried on at the New Hampshire Station,[e] the relative merits of timothy hay and corn stover were also studied. The rations consisted of 12 pounds of hay and corn stover alone or mixed, fed with 14 pounds of mixed grain. During the test, which covered nearly three months, the two sorts of coarse fodder were found equally satisfactory. Although the corn stover cost only one-third as much as the timothy hay, the conclusion was drawn that it has a feeding value equal to timothy hay fed with suitable mixtures of either corn and oats or corn and bran, and that when corn stover or timothy hay supplied the coarse fodder in a ration, oats and corn, half and half, and bran and corn, half and half, have generally equivalent feeding values.

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[a] Maryland Station Bul. 51.

[b] Virginia Station Bul. 80.

[c] North Dakota Station Bul. 20.

[d] North Dakota Station Bul. 45.

[e] New Hampshire Station Bul. 82.

Bermuda grass hay and timothy hay, fed in addition to corn, were compared with working mules at the Mississippi Station.[a] No marked differences in the cost of the rations nor in the gains made by the mules were observed.

The Oklahoma Station[b] reports a test in which Kafir corn stover was fed to horses and mules, the amount eaten by the horses averaging some 32 pounds per day and by the mules some 41 pounds. From this and tests of other farm animals the conclusion was drawn that Kafir corn stover is about equal in feeding value to corn stover, and that running stalks through a thrashing machine is a satisfactory method of preparing this feeding stuff.

At the Utah Station[c] a ration of timothy hay and grain was compared with one consisting of clover, oats, and wheat, two lots of work horses being used. The nutritive ratio of the first ration was 1:14.8; of the second, 1:5.5. For more than half the test the grains were fed unground. Somewhat better results were obtained with a ration having the narrower nutritive ratio. However, in a second test,[d] the ration having a wide nutritive ratio (1:15.2) gave results as satisfactory as the one having a narrower ratio (1:7.8).

Later, at the Utah Station, the comparative merits of alfalfa hay and timothy hay were investigated by L. A. Merrill[e] in tests with work horses and driving horses, which extended over four years. In some of the tests as much as 25 pounds of alfalfa or timothy hay with 10 pounds of bran and shorts was fed per head daily. In other tests the amount of hay was considerably smaller and the amount of grain larger. In some cases oats were fed instead of bran and shorts. Generally speaking, the timothy ration was the more expensive and the horses did not maintain their weight on it as well as on the alfalfa ration.

Tests were also made in which the feeding value of an alfalfa ration without grain was studied. It was found that 20 pounds of this material was sufficient to maintain the weight of a horse weighing nearly 1,400 pounds, provided no work was performed. When at hard work some 33 pounds of alfalfa hay was barely sufficient to maintain the weight. When the work was very severe 40 pounds of alfalfa hay was not an adequate ration, although it was about the limit which could be eaten. Regarding the experiments, the statement was made in effect that it is doubtful if there is any economy in feeding a horse 40 pounds of alfalfa per day. It is certain that better results can be secured by limiting the amount of hay to 20 pounds and substituting for the extra 20 pounds enough grain to make up the cost. This would secure at current prices [1902] 8 pounds of bran and shorts or 3.6 pounds of oats per day, and this amount with 20 pounds of alfalfa will make a better maintenance ration than 40 pounds of alfalfa. Aside from the financial consideration it should be emphasized that if digestive disorders are to be entirely avoided concentrated foods must make up part of the diet of the horse.

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[a] Mississippi Station Bul. 15.

[b] Oklahoma Station Rpt. 1899, p. 18.

[c] Utah Station Rpt. 1892, p. 30.

[d] Utah Station Bul. 30.

[e] Utah Station Bul. 77.

Considered as a whole the experiments are very favorable to the use of alfalfa hay as a coarse fodder for horses. The fact is recognized that, like other leguminous crops, it contains a larger amount of protein in proportion to its bulk than timothy. Feeding alfalfa did not exercise any bad effects on the health of the horses. It is stated that attacks of colic and other digestive disorders can be prevented by a judicious system of feeding. The amount of hay fed on most Utah farms, it is believed, could be reduced at least one-half. It may be economical to reduce the amount of hay and increase the amount of grain fed to horses. In this connection the author says:

> It is folly to claim that a horse will not eat more than is necessary if allowed the liberty of the stack and the grain bin. The argument is sometimes made that a horse under natural conditions, on pasture, never eats more than is necessary, and that under these conditions he is never subject to digestive disorders. While this is undoubtedly true, it must be kept in mind that as soon as we stable the horse and require work of him, we have taken him away from his natural condition and placed him under unnatural environments.

It was observed that larger amounts of water were consumed on the alfalfa ration and that the amount of urine excreted was also larger and had a higher specific gravity. The excess, however, was never found great enough to cause any inconvenience. These experiments at the Utah Station are especially interesting since they confirm the results of twelve years' practical tests of the feeding value of alfalfa. During this period the station horses have always received this material as a coarse fodder, except when they were fed other rations for experimental purposes.

From a study of the comparative digestibility of alfalfa hay and meadow hay by horses, Müntz and Girard[a] concluded that the former is superior as regards nitrogenous constituents and the latter as regards carbohydrates.

In studies at the Wyoming Station, undertaken by F. E. Emery[b] to determine what constituted maintenance rations for horses performing little work, alfalfa hay constituted the principal feed, no grain being supplied. It was found that farm horses required to perform very little work maintained their weight on an average daily ration, per 1,000 pounds live weight, of 13.75 pounds alfalfa hay and 2.25 pounds oat straw. A driving horse maintained his weight on a daily ration of 17.71 pounds alfalfa hay and 2.83 pounds oat straw per 1,000 pounds live weight.

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[a] Ann. Agron., 24 (1898), p. 5.

[b] Wyoming Station Press Buls. n. ser. 5, 10.

In discussing the subject of alfalfa for horses, the California Station[a] says in effect that in regions where it is a staple crop the quantity of protein which can be supplied in green and cured alfalfa is so great that much less grain is required than when the coarse fodder consists of cereal hays only. For the Pacific coast, where cereal hays replace so largely those from meadow grasses, the station recommends a ration of alfalfa hay with wheat hay or barley hay and grain.

In a recent discussion of the problem of horse feeding under local conditions, Director Stubbs,[b] of the Louisiana stations, emphasizes the value of cowpea vine hay.

The outcome of the different experiments is in accord with the observation of careful feeders, viz, that the various common coarse fodders may be fed to horses as circumstances demand. Although timothy hay is in many regions regarded as the preferable coarse feed, yet experience has shown that corn fodder, hay from wheat, barley, and other cereal grains, and from clover, and alfalfa may be substituted for it. That this is what might be expected is shown by a study of the composition of these feeding stuffs. As will be seen by reference to the table above (p. 13), they resemble each other very closely in the character and amount of nutrients which they contain—alfalfa, clover, and other leguminous hays being richer in protein than the cured grasses and cereal forage. Straw is not much fed to horses in the United States, but is a common feeding stuff in Europe. As shown by its composition and digestibility (pp. 14, 41), it compares quite favorably with other coarse fodders. The substitution of one coarse fodder for another in a ration should always be made on the basis of composition and digestibility, rather than pound for pound.

Very few tests have been made on the comparative value of different uncured feeds or different sorts of pasturage in horse feeding, though all the common forage crops are regarded as wholesome if properly fed. In discussing green crops for horses, [c] Lavalard says:

> Such feed is very dependent upon the fertilizer used for the crop, the method of harvesting, and the condition of the animal fed. Green fodder does not contain sufficient nutritive material to make it in any real sense a feeding stuff for horses performing much work. The same may be said of certain plants which have been much advertised from time to time, such as furze, couch grass [sacchaline], etc.

ROOTS AND TUBERS.

Carrots, Swedish turnips or ruta-bagas, and other roots and tubers, green vegetables, and fruits contain a high percentage of water and small amounts of the different classes of nutrients. Generally speaking, the percentage of crude fiber is smaller than in the green forage crops; but since the proportion of nutritive material is small in comparison with the total bulk, they are ordinarily referred to as coarse fodder. The use of these materials as food for horses has been attempted at different times with varying success, but it is not followed to any great extent in this country. In the opinion of a recent German writer, about 12 pounds of raw potatoes per 1,000 pounds live weight may be fed to horses with advantage and, if supplemented with proper feed, there need be no fear of physiological disturbances. When fed in this amount the potatoes should be mixed with hay or cut straw to insure their being properly chewed. If small, they may be fed whole; if large, they should be sliced. In any case only healthy, ripe, unsprouted tubers should be used. It is said that horses should not be watered immediately after a ration containing potatoes.

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[a] California Station Bul. 132.

[b] Loc. cit.

[c] Experiment Station Record, 12 (1900–1901), p. 4.

MOLASSES AND OTHER BY-PRODUCTS OF SUGAR MAKING.

The beet chips, diffusion residue, and other by-products obtained in the manufacture of beet sugar, consist of the sugar beet from which a considerable portion of the carbohydrates has been removed. The total amount of nutritive material present, however, is fairly large. These products, properly speaking, are also coarse fodders. Molasses, which consists almost entirely of carbohydrates (sugars), was used as early as 1830 as a feed for horses, and has recently attracted considerable attention in this connection. When used for this purpose it is usually sprinkled on dry feed, being first diluted with water, or it is mixed with some material which absorbs it and renders it easy to handle, such as peat dust, or with some material rich in nitrogen, as dried blood. In the latter case the mixture more nearly represents a concentrated feed than the molasses alone, or molasses mixed with an absorbent material only. Cane-sugar molasses is also used as a feeding stuff. It differs from beet molasses in that it contains glucose in addition to cane sugar, and has a much smaller percentage of salts.

In this connection the experiments reporting the successful feeding of cane molasses to over 400 work horses at a sugar plantation in the Fiji Islands[a] are of interest. As high as 30 pounds of molasses was fed per head daily at different times, but the ration finally adopted consisted of 15 pounds of molasses, 3 pounds of bran, and 4 pounds of maize. In addition, green sugar cane tops were fed. The health of the horses remained excellent. Molasses did not cause diarrhea, but rather constipation, which was counteracted by feeding bran. Feeding molasses effected a saving of over $45 per head per annum. However, it was believed that such a saving was possible only by reason of large quantities of waste molasses and valueless cane tops available on the spot. In discussing these experiments the following statements were made:

> For working horses the sugar in cane molasses is a satisfactory substitute for starchy food, being readily digested * * * and 15 pounds can be given to a 1,270-pound working horse with advantage to the health of the animal and to the efficiency of its

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[a] Agr. Gaz. New South Wales, 9 (1898), p. 169.

> work. It produces no undue fattening, softness, nor injury to the wind. The high proportion of salts in it has no injurious effect. An albuminoid ratio as low as 1:11.8 has proved highly suitable for heavy continuous work when a sufficient quantity of digestible matter is given.

According to W. C. Stubbs,[a] of the Louisiana stations, cane-sugar molasses has been used extensively with success for a number of years for feeding horses and mules in Louisiana, many feeders keeping mules exclusively on a ration of rice bran and molasses in addition to cowpea hay. The general custom is to feed the molasses from a large trough, allowing the mules to eat it ad libitum. It is said they will consume with apparent relish from 8 to 12 pounds per head daily. The mules at the Louisiana stations have been fed molasses daily ad libitum for eight or ten years, and, according to Director Stubbs, show its good effects "in their splendid condition, lively action, and endurance of work."

In this connection it is interesting to note the results obtained by G. E. Griffin[b] in the experimental feeding of cane-sugar molasses to army horses in Porto Rico. In accordance with the local custom, this material was fed with chopped grass, the ration being gradually substituted for the usual ration of oats and hay. The molasses was diluted with 25 per cent of water, and as much as possible was mixed with the chopped grass. The remainder was added to the drinking water. The test reported continued some five months and led to the deduction that 35 pounds of grass and 13 to 15 pounds of molasses daily per 1,000 pounds live weight is sufficient to maintain a horse in good condition in a climate like that of Porto Rico. This method of feeding, it was believed, had some disadvantages, which were as follows:

> Molasses attracts insects, notably flies and ants; it sticks to the animal's coat, smears his face and breast, halter and halter strap, soils the clothing and equipment of the men, and causes some trouble and delay in mixing it with the grass, which must be cut fine.

G. H. Berns[c] reports the successful feeding of molasses to 100 draft horses working ten hours a day hauling very heavy loads usually at a walk. The horses averaged 1,700 pounds in weight and were fed per head, night and morning, 1 quart of molasses diluted with 3 quarts of water and thoroughly mixed with 6 pounds of cut hay of good quality, 1.5 quarts of corn meal, and 2.5 quarts of coarse bran. In addition they were fed 5 quarts of dry oats in the middle of the day and 11 pounds of long hay at night. It is stated that the horses gradually improved in condition and gained in weight during the fourteen months covered by the test, their coats becoming sleek and glossy, while the amount of work performed was the same as before the molasses ration was adopted. In the meantime their general health is said to have been excellent, and cases of acute indigestion or spasmodic colic very rare, although formerly quite frequent. The molasses ration was decided upon after its value had been demonstrated in a test with two horses. A ration similar to the above was also fed with success to a number of driving horses.

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[a] Loc. cit.

[b] Amer. Vet. Rev., 25 (1901–2), p. 894.

[c] Amer. Vet. Rev., 26 (1902–3), p. 615.

In general, no disturbance was observed in changing from an ordinary to a molasses ration. As part of a mixed ration, the author calculates that 1 quart of molasses will replace 3 to 4 quarts of oats of good quality. He believes that "molasses of a good quality is a most nutritious food for horses, easily digested and assimilated, and will in many cases correct faulty digestive processes," and that "molasses-fed horses will do fully as much work and at the same time remain, as a rule, in much better general condition than animals fed on dry food, while the cost of feeding is reduced from 25 to 33 per cent."

As an outgrowth of this work Dr. Berns states that molasses has been successfully fed, under his direction, to 2,500 or 3,000 horses.

The value of beet-sugar molasses as a part of a ration for horses and other farm animals was tested several years ago by Dickson and Malpeaux[a] in France. The test with horses was made with four animals fed a total ration of 15.4 pounds of oats, 11 pounds of alfalfa hay, and 11 pounds of wheat straw. Molasses was gradually substituted for part of the oats, until 13.2 pounds of the latter and 2 of the former were fed. The molasses was mixed with the drinking water. The feeding was continued for about six weeks, and all the horses gained slightly in weight. The authors regard the substitution of molasses for part of the oats as entirely satisfactory, since it was readily eaten and the vigor and weight of the horses were maintained.

Grandeau[b] has very recently described a number of practical tests in which molasses mixtures were added to the rations of horses. The cost of the ration was diminished and the health and condition of the animals maintained. Similar results have been reported by other investigators in France and by Wibbens[c] in Holland. From all these investigations it seems fair to conclude that molasses can be safely fed to horses when its cost in comparison with other feeding stuffs warrants its use. Apart from the nutritive material it supplies, it has a value as an appetizer and frequently renders poor hay or other feed more palatable.

The feeding value of blood molasses (a mixed feed containing dried blood and beet-sugar molasses) was studied in Denmark[d] with 23 horses belonging to a Copenhagen milk company. The horses were divided into two lots. One lot was fed a ration of barley and oats 1:2

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[a] Ann. Agron., 24 (1898), p. 353.

[b] Jour. Agr. Prat., n. ser., 4 (1902), pp. 569, 599, 697.

[c] Cultura, 14 (1902), p. 520.

[d] Landmandsblade, 32 (1899), p. 349.

during part of the test, and later of oats and hay. Lot 2 was fed the same ration except that blood molasses was substituted for part of the grain in the ratio of 1 pound to 2 pounds; 2.5 pounds to 3 pounds, and, later, of 3 pounds to 4 pounds. This latter ratio represents about what was considered the comparative value of the molasses feed. In earlier Scandinavian experiments[a] the successful feeding of 2.2 pounds of beet-sugar molasses per head daily to work horses was observed; other similar tests might be cited.

FRUITS, FRESH AND DRIED.

Although horses are often given apples as they are given lumps of sugar, fruit is not generally thought of as a feeding stuff, yet its use for this purpose is by no means novel. The Arabs, according to E. Daumas,[b] commonly feed their horses fresh dates. In such dates the pits are soft and are eaten with the pulp. Sometimes 3 or 4 pounds of fresh dates are mixed with water to a sort of mush before feeding. It is believed that dates are fattening, but that they do not produce muscle.

In California and possibly in other regions fruit, especially prunes and other dried fruit, is sometimes fed when the market is overstocked or when for some other reason it can not be profitably sold. According to a recent statement,[c] small prunes of low market value have been successfully fed to horses for a long period. It is stated that the horses eat them with relish. The pits should be crushed before feeding.

The California Station[d] has reported analyses of a number of fresh and dried fruits and discussed their value as stock feed. A recent report of the Arizona Station[e] gives the composition of almond hulls or pericarps, the portion of the almond removed before the nut is marketed, and states that this material has been found to be a fattening feed for horses.

All common fruits when fresh are very succulent, containing on an average 80 to 90 per cent water, the nutritive material consisting almost entirely of carbohydrates. When dried—i. e., concentrated by evaporation—they are much more nutritious. Raisins, prunes, dried peaches, etc., contain about 25 per cent water and about 70 per cent carbohydrates, of which a considerable part is sugar. The value of sugar as a nutrient is recognized, and it is not surprising, therefore, that fruits, especially after drying, should have a considerable feeding value.

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[a] K. Landt. Akad. Handl. Tidskr., 34 (1895), p. 246.

[b] Les Chevaux du Sahara. Paris: Calmann Lévy, 1887, p. 134.

[c] Pacific Rural Press, 60 (1900), p. 402.

[d] California Station Bul. 132.

[e] Arizona Station Rpt. 1902, p. 269.

INJURIOUS FEEDING STUFFS.

In feeding horses precautions should always be taken to avoid materials harmful in themselves, or those which have become harmful. Dirt, small stones, etc., should be removed from grain by proper screening, and all feeding stuffs should be clean. On this subject Lavalard[a] says:

> Some of our recent experiments have had to do with the methods of feeding. They cover a number of points. The first and perhaps the most important is the advantage of cleaning the grain. Grandeau showed in his experiments that oats could be satisfactorily freed of foreign grains and impurities by some of the well-known screening devices. He studied the composition of the impurities, and found that some of them were injurious to the health of the horses.
>
> The importance of proper cleaning is illustrated by a point in our own experience. A few years ago, after a very severe drought, we were compelled to feed oats containing tares and leguminous seeds, some of which were those of the species of Lathyrus. Symptoms of Lathyrus poisoning were noted in a number of horses. The attacks were frequently severe and sometimes fatal. When oats were properly cleaned this trouble was entirely obviated. Cleaning also increases the density of the oats by removing mineral matter and dust, which may sometimes induce attacks of intestinal obstruction, colic, etc.

There are a number of plants which are poisonous to horses when eaten in any considerable amount. The loco plants, mostly species of Astragalus, are ordinarily regarded as of this class. These plants have been studied by the Colorado, Kansas, South Dakota, Montana, and Oklahoma stations among others, and by this Department, but the results obtained are not entirely conclusive. The poisonous properties of rattlebox (*Crotalaria sagittalis*) were demonstrated by the South Dakota Station, and those of some lupines by the Montana Station. According to recent experiments at the Vermont Station[b] the common horsetail (*Equisetum arvense*) may cause poisoning when present in hay. It was found that when horses were fed cured horsetail equal in amount to not more than one-fourth of their coarse fodder ration, symptoms of poisoning were noticed, and if the feeding was continued the horses died. The symptoms of poisoning were less noticeable with young than with old horses, and also when a liberal grain ration was supplied. It was also observed that the green plant was less harmful than the dry, possibly owing to the fact that green fodder is somewhat laxative.

Feeds which are ordinarily wholesome may under certain conditions be harmful. Thus there is a widespread and apparently justifiable prejudice against moldy or decomposing feeding stuffs. Experiments carried on at the Kansas and Indiana stations showed that the continued feeding of moldy corn induced intestinal and nervous disorders of a serious nature. It is a matter of common observation that food which has been wet will ferment or sour readily and cause intestinal disorders. This has to be guarded against especially in warm climates. Plants which are ordinarily wholesome may become harmful if infested with ergot. The effect of ergot on horses has been studied by the Iowa, Kansas, and Montana stations and others. It is generally conceded that the presence of ergot is a cause of rheumatism. Some feeds which are regarded as wholesome when properly fed may sometimes prove injurious if fed for a long time, or in improper quantities. Thus, millet hay, in many sections of the Western United States, is believed to cause the so-called millet disease of horses. This question was studied by the North Dakota Station.[a] It was found that long-continued feeding of millet hay caused lameness and other symptoms of poisoning. From the experiments and observations the conclusion was drawn that feeding millet alone as a coarse fodder is injurious to horses, since it produces an increased action of the kidneys and causes lameness and swelling of the joints and an infusion of blood into the joints. It may also injure the texture of the bones, rendering them soft and less tenacious. The bad effects due to long-continued feeding of millet were observed whether the crop was cut just when the heads were fully ripe or earlier, although there is a popular belief that the trouble is due to harvesting the crop before the heads are fully ripe. The investigation seemed to show conclusively that feeding millet produced millet disease, but the specific cause to which the dangerous properties of millet are due was not learned, though later work at the station indicates that it is a glucosid.

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[a] Loc. cit.

[b] Vermont Station Bul. 95.

An explanation of the poisoning of stock by young sorghum and some other forage plants is offered by the discovery by Dunstan and Henry[b] of a cyanogenetic glucosid in a number of varieties of sorghum (*Sorghum vulgare*), which under the influence of a special ferment present in the plant liberates prussic acid. It is thought probable that this acid may be likewise liberated in the digestive tract of animals feeding on the young plants. They did not find the glucosid in the mature sorghum. For a number of years Peters, Avery, and Slade,[c] at the Nebraska Experiment Station, have studied sorghum poisoning, and have recently demonstrated the presence of cyanic acid in the green leaves of young and old sorghum plants and Kafir corn.

METHOD OF FEEDING.

The method of feeding is a subject which is often discussed, the questions of especial interest being the comparative merits of cooked and raw feed, dry and soaked grain, ground and unground grain, and cut or chaffed and uncut coarse fodder. The number of experiments which have to do with these topics is not numerous.

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[a] North Dakota Station Buls. 7, 26, and 35.

[b] Proc. Roy. Soc. [London], 70 (1902), p. 153.

[c] Nebraska Station Rpt. 1902, pp. 50, 55; Jour. Comp. Med. and Vet. Arch., 23 (1902), p. 704; Jour. Amer. Chem. Soc., 25 (1903), No. 1, p. 55.

COOKED AND RAW FEED.

Boussingault compared oats and an equal volume of rye boiled until the grain burst. The results were not favorable to cooking the feed. According to another of his tests 30.8 pounds of mashed steam potatoes could not replace 11 pounds of hay. The potatoes were mixed with cut straw and fed cold.

It is often claimed that cooking feed increases its palatability and digestibility. The general conclusion drawn from tests with farm animals is that this belief is not warranted and that the cost of cooking is not made up for by the increased value of the ration. Prof. W. A. Henry[a] states that boiled feed is useful for colts, brood mares, and stallions if fed two or three times per week, and that draft horses which are being prepared for sale or for exhibition may be given cooked feed once a day. In his opinion an excellent feed for horses is made by boiling barley and oats in a kettle with considerable water and pouring the mass over chaffed hay, allowing the whole to stand until the hay is well softened. Bran, roots, and a small quantity of oil meal may be added also.

DRY AND SOAKED FEED.

It is often said that soaking feed, especially hard grain, renders it more easily masticated and improves its digestibility. It is doubtful if the matter is as important with horses as some other classes of farm animals. According to Wolff[b] healthy horses with good teeth digested dry beans and corn as well as the same materials which had been soaked in water for 24 hours.

Soaking or wetting feed may sometimes be of importance as regards the health of horses. According to the experience of an English feeder[c] chaffed straw, which was fed on account of a shortage in the hay crop, gave better results when soaked than when dry. The dry material caused colic and constipation. It was also observed that the horses relished soaked grain (corn and oats 1:1).

It is believed that the dust in hay causes heaves, and to avoid such trouble both long and cut hay, especially clover, is very often dampened before feeding to lay the dust.

GROUND AND UNGROUND FEED.

Opinions differ as regards the advantages of grinding grain. In Professor Henry's[a] opinion, for horses which are out of the stable during the day and worked hard, all grains, with the possible exception of oats, should be ground, and for those at extremely hard work, all grain should be ground and mixed with chaffed hay. For idle horses, oats or grain should not be ground, nor should hay or straw be chaffed. In other words, provided the animals have time to masticate their ration thoroughly, grinding is not necessary. When this is not the case, grinding takes the place of thorough mastication to some extent and increases the assimilation of the ration.

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[a] Loc. cit.

[b] See footnote, p. 60.

[c] Live Stock Jour., 39 (1894), p. 30.

When whole oats were compared with ground wheat and bran by Shepperd[a] at the North Dakota Station the horses fed the former ration ate somewhat more, and showed a slight loss in weight, while doing a little less work than those fed the ground grain.

In a test of the comparative merits of timothy hay and corn and clover, oats, and wheat made with two lots of work horses at the Utah Station[b] the grains were fed unground for somewhat more than one-half of the experimental period and ground during the remainder of the period. The ground and unground grains were regarded as equally satisfactory.

At the Iowa Station Wilson and Curtiss[c] compared whole and ground grains (oats, corn, and barley) for colts, and found that somewhat larger gains were made on the ground feed.

In the study of the digestibility of the different feeding stuffs carried on at the Maryland Experiment Station Patterson[d] compared a number of whole and ground feeds. His results show that ground oats and corn were more thoroughly digested than the unground grain. In this connection it should be noted that similar results have been obtained in tests with other farm animals, but it is commonly believed that the difference in digestibility is often not sufficient to pay for the additional cost of grinding.

From the American tests and those which have been made in Europe it appears fair to say that there is no very marked advantage in grinding grain for healthy horses with good teeth. Lavalard says:

> Contrary to the opinion of some experts, the writer believes it is not necessary to grind grain for horses. This is especially true in the case of oats. In some of our earlier experiments, where ground grain was fed, it was noticed after a few months that the horses preferred to crush it themselves. Of course this does not refer to old horses [i. e., horses having poor teeth]. They can be fed ground grain to advantage.

CUT AND UNCUT COARSE FODDER.

It is perhaps the general opinion that when horses have ample time for chewing and digesting their feed there is no necessity for chaffing or cutting hay and straw. When the time for feeding is limited chaffing and cutting coarse fodder is regarded as advantageous. This is an item of special importance with hard-worked horses kept in the stable only at night. Furthermore, chaffed feed occupies less space for storage than uncut hay or straw and can be readily handled.

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[a] North Dakota Station Bul. 20.

[b] Utah Station Bul. 30.

[c] Iowa Station Bul. 18, p. 470.

[d] Maryland Station Bul. 51.

Shredding corn fodder is regarded as an economical practice, but apparently few experiments on the comparative merits of shredded and whole corn fodder for horses have yet been reported. No marked variation was observed in the weights of two lots of horses fed whole and cut timothy or whole and cut alfalfa and clover hay mixed in a test carried on at the Utah Station.[a]

At the Maryland Station Patterson,[b] who studied the digestibility of a number of whole and ground feeds, found that grinding corn shives—i. e., cornstalks from which the blades, husks, and pith are removed—until the material resembled coarse bran did not destroy its value as a coarse fodder and that the finely ground material supplied the necessary bulk to the ration as well as the same material unground. It was further claimed that the finely ground coarse fodder possessed an advantage over the unground material in that it could be mixed with grain to form a well-balanced ration and fed to horses on shipboard, or under similar conditions, more readily than unground fodder and grain.

COST OF A RATION.

The cost of a ration made up of the ordinary grains and coarse fodders has been investigated by at least three of the American experiment stations. The Massachusetts Hatch Station[c] recorded the kinds and amounts of foods consumed by three farm horses for five years, with a view to learning the average cost of the daily feed. In the different years the cost of the ration, which consisted of hay, corn, oats, and other common feeding stuffs, varied from 18.5 to 24.8 cents per head daily.

At the Oklahoma Station[d] statistics of the cost of feed of work horses were also recorded in tests of the comparative value of Kafir corn and maize. Red Kafir corn and maize at 20 cents per bushel, oats at 25 cents per bushel, and bran at 25 cents per hundredweight were used. The average cost per horse of a day's labor was estimated to be 17 cents.

Using mixed-grain rations, according to the New Hampshire Station,[e] the average cost of feed per horse per year was $74.32. The average cost for feed per hour's work performed during the two years covered by the test was 3.4 cents.

The data recorded above are too limited for general deduction.

FATTENING HORSES FOR MARKET.

Fattening horses so that they will reach market in good condition for sale is quite an important industry in some regions. For instance, in Iowa there are a number of feeders who thus prepare large numbers of horses for the Chicago market. Though few, if any, experiments have been carried on at the stations to show the feed required per pound of gain, the relative cost of gain, etc., J. A. Craig and H. W. Brettell,[a] of the Iowa Station, have described this industry on the basis of data gathered from local feeders extensively engaged in it.

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[a] Utah Station Bul. 13.

[b] Maryland Station Bul. 51.

[c] Massachusetts Hatch Station Rpt. 1893, p. 179.

[d] Oklahoma Station Rpt. 1899, p. 31.

[e] New Hampshire Station Bul. 82.

The horses are usually purchased in the fall, after the farm work is over, and are stabled and fed an abundant ration, care being taken to accustom them gradually to full feed in order to avoid colic. When on full feed the horses studied were given, per head, 10 to 14 ears of corn in the morning, at noon, and again at night, with 3 quarts of oats and bran 1:2 and hay ad libitum in the middle of the forenoon and also in the middle of the afternoon. Recognizing the importance of a long period of rest, no feed was given from 6 or 7 at night until 5 o'clock in the morning. The horses were watered twice a day and were given all they would drink. On account of the large number fed, the horses could not be exercised, but as a rule were kept idle in the stable until a few days before they were marketed. To insure good condition it was found advantageous to give 0.5–0.75 pint Glauber salts per head twice a week. Oil meal, it is stated, may also be given to good advantage, as it aids greatly in putting on flesh and also makes the skin soft.

The importance of keeping mangers and feed boxes clean is insisted upon, and attention is especially directed to the need of examining the horses' teeth and removing with a float any sharp points which would make the gums sore and thus prevent the horses from masticating their feed properly.

With such feeding and care satisfactory gains were generally realized. In one instance, it is stated, a horse fed in this manner made a gain of 5.5 pounds per day for a period of fifty days, or 550 pounds in one hundred days. In several instances, with as many as a dozen horses, a gain of 3.75 pounds per head per day was obtained throughout a period of ninety days.

WATERING HORSES.

A discussion of the subject of watering horses should take into account the reasons why water is needed, the amounts required, the proper time for watering, and related topics.

Horses, like other animals, require water to moisten their food so that the digestive juices may permeate it readily, to dilute the blood and other fluids of the body, and for other physiological uses. It may be assumed that under any given normal condition the body contains a definite amount of water. When any considerable amount of water is lost from the body, a sensation of thirst is experienced, showing that more water is needed to take its place. Practically all the water excreted leaves the body in the feces, urine, perspiration, and breath. The amount eliminated in each, according to Wolff,[a] increases with the amount of water consumed, the largest amount being excreted in the feces. In experiments which he carried on, the total amount of water consumed ranged from 17.363 kilograms to 34.272 kilograms (38.3 to 75.6 pounds). The feces contained from 40.3 to 47.3 per cent of the total amount excreted; the urine from 21.2 to 34.9 per cent.

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[a] Breeders' Gaz., 35 (1899), p. 781.

In addition to the water drunk by horses, a considerable amount is obtained in the more or less succulent food eaten. The amount of water required is influenced by a number of factors, including the season of the year, temperature of the surrounding air, character of the feed, the individual peculiarities of the horse, the amount and character of the work performed, and probably others. The amount of water needed increases with the temperature and with the amount of work performed, since it is very evident that both of these factors increase the amount which is given off from the body in the form of perspiration. Muscular work also increases the amount of water vapor excreted in the breath. According to Grandeau and Leclerc,[b] a horse used in one of their experiments, when at rest, evaporated 6.4 pounds of water per day; when walking, 8.6 pounds; when walking and drawing a load, 12.7 pounds; when trotting, 13.4 pounds, and when trotting and drawing a load, 20.6 pounds. It is evident from these figures that the amount of water excreted, and hence the amount required, varies with the work performed.

It has been found that less water is required when the ration consists largely of concentrated feed than when large amounts of coarse fodder are consumed, and it is a matter of common observation that less water is consumed when green, succulent feeds form a considerable part of the ration than when it consists of dry feed. That the amount of water taken, even in dry feed, may be considerable is shown by the fact that a ration of 12.1 pounds oats and 15.4 pounds hay, according to Wolff's[a] calculation, furnishes some 4.1 pounds water. A succulent ration would furnish much more. In Grandeau and Leclerc's experiments with the Paris Cab Company's horses it was found that with a mixed ration the average proportion of water drunk to dry matter supplied was 2.1:1 when the horses were at rest, and 3.6:1 when they were used for cab work. In some of Wolff's experiments the proportions varied from 2.35:1 to 3.5:1. The effect of the amount of work performed and of individual peculiarities on the amount of water required is illustrated by the following figures obtained by Grandeau and Leclerc: Two horses consumed respectively 24.9 and 30.7 pounds of water per day when their work consisted only of walking; when the horses walked and in addition drew a load, the amounts of water consumed were 28.9 and 35.4 pounds; when trotting without a load, 31.3 and 27:6 pounds, and when trotting and drawing a load, 52 and 50.7 pounds, respectively.

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[a] Landw. Jahrb., 1887, Sup. 3.

[b] Ann. Sci. Agron., 1888, II, p. 276.

In a number of feeding experiments carried on with horses at the experiment stations in the United States the amount of water consumed has been recorded. In tests at the New Hampshire Station,[a] in which the ration consisted of different grain mixtures, with timothy hay and corn fodder, it was found that the quantity of water consumed varied from 70.94 pounds to 90.4 pounds per horse per day. It was observed that both the ration consumed and the amount of work performed influenced the quantity of water drunk, although the individuality of the horse had the most marked effect.

The amount of water consumed by horses on rations of timothy hay and alfalfa hay (with oats) was studied at the Utah Station.[b] It was found that on an average larger amounts were consumed with the latter than with the former, the average amounts per day being some 78.51 and 88.85 pounds, respectively. The greater consumption of water on the alfalfa ration induced a greater elimination by the kidneys, but so far as could be observed this was not attended by any bad results nor was it found inconvenient.

At the Oklahoma Station[c] a pair of mules, during hot summer weather, drank 113 pounds of water per head daily, and on one day the pair drank 350 pounds. On an average a pair of mules and horses, each weighing 2,130 pounds, drank 107 pounds of water per head per day while at moderate work. In these tests the grain ration consisted of Kafir corn, maize, oats, and bran.

The proper time to water horses is a matter concerning which opinions differ. Many feeders believe that they should be watered before feeding, while others are equally certain that feeding should precede watering. Experiments made on this subject at the Utah Station did not lead to definite conclusions.

The subject was recently investigated by Tangl[d] at Budapest. The rations fed consisted of different mixtures of corn, oats, hay, and straw, and a number of experiments were made in which the only condition which varied was the time of watering. In some of the tests the horses drank before and in some after eating, and in others after the grain portion of the ration was eaten but before the hay.

Regarding these experiments Professor Tangl makes in effect the following statement: So far as was observed the time of drinking had no effect on the digestibility of a ration of grain and hay. When hay only was fed there seemed to be a slight advantage in watering before feeding. In general, horses may be watered before, during, or after meals without interfering with the digestion and absorption of food. All these methods of watering are equally good for the horse, and each of them may be employed, according to circumstances. It is obvious that certain circumstances may make it necessary to adopt one or other method. For instance, after severe loss of water, such as occurs in consequence of long-continued, severe exertion, the animal should always be allowed to drink before he is fed, as otherwise he will not feed well. Although all methods of watering are equally good for the horse, it is not desirable to change unnecessarily from one method to another. Animals, or at least some of them, appear to be not altogether indifferent to such a change. In the experiments referred to above it was found that whenever a change was made from the plan of watering after feeding to that of watering before, the appetite fell off for some days; not that the horses did not consume the whole of the food given to them, but for some days together they did not eat with the same avidity as before, and took a longer time to consume their rations completely. A similar effect was not observed when the change was from watering before to watering after feeding, or from watering after to watering during meals, or when the change was in the opposite direction to the last. It is possible that the method of watering before feeding, until the animal has become accustomed to it, produces a certain feeling of satiety. The time of drinking exercised a marked effect on the amount of water consumed and upon the amount of water excreted. The horses drank the greatest amount of water when it was given after feeding and the least when it was supplied before feeding. This was especially noticeable in the morning when water was sometimes refused if offered before feeding. The excretion of urine was directly proportional to the amount of water consumed. When it is desired to increase the excretion, the author recommends watering after feeding. The method of watering had no effect upon the amount or qualitative composition of the feces. Body weight varied with the amount of water consumed.

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[a] New Hampshire Station Bul. 82.

[b] Utah Station Bul. 77.

[c] Oklahoma Station Rpt. 1899, p. 31.

[d] Landw. Vers. Stat., 57 (1902), p. 329; Twentieth Century Farmer, 1892, No. 82, p. 1.

DIGESTIBILITY OF FEEDING STUFFS.

In the preceding pages reference has been made to the composition of different feeding stuffs and to the tests of the comparative value of different concentrated feeds and coarse fodders. The real value of any feeding stuff is determined, not alone by its composition, but also by its digestibility; that is, by the amount of material which it gives up to the body in its passage through the digestive tract. It is evident that if two feeding stuffs have practically the same composition, but one gives up more material to the body than the other, that is, is more thoroughly digested, it must actually be more valuable than the other material. The bulk of the substance of almost all feeding stuffs is insoluble when eaten. Only material in solution can pass through the walls of the stomach and intestines into the circulation and be utilized by the body, therefore digestibility consists chiefly in rendering insoluble materials soluble. This is effected by the aid of digestive ferments and also by bacteria.

Digestion experiments are frequently made to learn how thoroughly a given feeding stuff or ration is assimilated. The usual method is to feed the material under consideration for a longer or shorter time, the amount and composition being determined. From the total nutrients consumed, the amount excreted and undigested in the feces is deducted, showing the amount of each retained in the body. It is the usual custom to express the amounts digested in percentages, the results thus obtained being termed coefficients of digestibility.

The digestibility of a number of different feeding stuffs has been tested with horses in this country and in Europe, although the number of such experiments is much smaller than in the case of cattle and sheep. The most extended series of American experiments with horses was carried on by Patterson[a] at the Maryland Experiment Station. In the table below the American and foreign digestion experiments with horses are summarized. In a few cases values obtained with ruminants are also included in the table, since no coefficients of digestibility, obtained with horses, were available, and the data were needed in computing the value of rations discussed later (p. 48).

TABLE 2.—*Summary of coefficients of digestibility obtained in experiments with horses.*

Kinds of fodder.	Coefficients of digestibility.			
	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Alfalfa, uncured	78.2	....	81.0	46.8
Alfalfa hay	74.6	19.1	70.2	39.0
Alfalfa (hay) stalks	72.6	....	63.9	40.3
Alfalfa (hay) leaves	75.5	....	76.6	52.1
Red clover hay	55.7	28.7	63.5	37.4
Meadow hay, best quality	63.5	22.0	65.5	48.2
Meadow hay, medium quality	57.5	18.0	58.1	39.0
Meadow hay, poor quality	54.6	23.6	52.2	37.6
Meadow hay, average	57.1	20.7	56.7	39.7
Timothy hay	21.2	47.3	47.3	42.6
Corn stover[b]	64.1	73.6	68.2	73.8
Ground corn shives	67.5	59.8	47.0	54.6
Wheat straw	27.7	65.7	28.1	17.7
Spelt straw	22.9	20.2	17.9	30.0
Corn silage[c]	49.3	80.0	68.6	66.7
Carrots	99.3	....	93.8	....
Potatoes	88.0	....	99.4	9.1
Shelled corn	57.8	47.7	88.2	....

[a] Maryland Station Bul. 51.

[b] Coefficients of digestibility of corn fodder as fed to ruminants.

[c] Coefficients of digestibility as fed to ruminants.

TABLE 2.—*Summary of coefficients of digestibility obtained in experiments with horses*—Continued.

Kinds of fodder.	Coefficients of digestibility.			
	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Corn meal	76.0	67.1	93.9	20.2
Oats	79.6	72.1	75.8	29.7
Ground oats	82.4	79.9	86.1	14.4
Wheat [a]	79.6	72.1	75.8	29.7
Rye	80.3	42.4	87.3	[b] 100.0
Cotton-seed meal [c]	88.4	93.3	60.6	55.5
Field beans	85.9	13.2	93.6	65.4
Lupine seeds	94.2	27.3	50.8	50.8
Peas	83.0	6.9	89.0	8.0
Wheat bran [c]	77.8	68.0	69.4	28.6
Wheat shorts [d]	77.8	68.0	69.4	28.6
Dried brewers' grains [c]	79.3	91.1	57.8	52.6
Gluten meal [c]	88.2	94.4	89.8	....
Linseed meal [c]	85.2	96.6	86.1	80.4
Molasses	100.0	....	100.0	....

[a] As oats, no coefficients of digestibility of wheat having been found.
[b] This value is without doubt much too high.
[c] Coefficients of digestibility as fed to ruminants.
[d] As bran, no coefficients of digestibility of shorts having been found.

In addition to the experiments reported above, a number have been found on record which show the digestibility of a mixed ration, but, generally speaking, the total number of digestion experiments with horses is small and, as will be seen, the tests are limited to a comparatively small number of feeding stuffs. Some 36 experiments were found on the digestibility of oats and 30 on the digestibility of meadow hay. The total number reported with alfalfa hay was 12, and in all other cases the number was very small. It is evident that more digestion experiments are needed with some of the common feeding stuffs, and that the digestibility of many additional materials should be studied.

As will be seen in the majority of feeding stuffs, the percentage of protein digested is fairly high, greater in grains and seeds than in hay and grasses, and least in the case of timothy hay and spelt straw. The high values reported in the table for protein of carrots and molasses need some explanation. The percentage of protein in the former is comparatively small, and it is doubtful if the figures reported show the actual digestibility, as it is difficult to determine in the case of a nutrient present in small quantities. In the case of molasses, the greater part of the nitrogenous material consists of amids or other nonalbuminoid bodies. It should be remembered that neither carrots nor molasses is fed for protein, but rather for the carbohydrates which they contain.

Generally speaking, the values obtained for the digestibility of fat are rather low, the fat of oats being most digestible and that of peas least digestible. In general it has been found that the determination of the coefficients of the digestibility of fat presents more difficulty than that of other nutrients.

It will be seen that nitrogen-free extract is quite thoroughly assimilated, the values ranging from 100 per cent in the case of molasses to 17.9 per cent in the case of spelt straw. The high value obtained for the digestibility of this nutrient in molasses is doubtless due to the fact that carbohydrates exist in it in soluble forms and hence in a condition very favorable for assimilation. Possibly the comparatively small amount of crude fiber present in carrots and potatoes accounts for the high digestibility of the starch which makes up the greater part of the nitrogen-free extract of these feeds. The principal sources of nitrogen-free extract in the ration are the cereal grains and their by-products, and it is interesting to note that the coefficients of digestibility of nitrogen-free extract of these materials is high. In the majority of feeding stuffs the crude fiber is not very thoroughly digested, the coefficients of digestibility being on an average less than 50 per cent. The high value given in the above table for the crude fiber of rye is unusual, and should be confirmed by further experiments before it can be accepted.

The digestibility of the different materials which make up the carbohydrate group has been recently studied by Weiser and Zalischek[a] with horses and other farm animals. The following table shows the results obtained with a horse fed different combinations of meadow hay, broom-corn seed, and oats.

TABLE 3.—*Digestibility of different carbohydrates by a horse.*

Rations.	Cellulose or crude fiber.	Starch.	Pentosans.	Undetermined constituents.	Total nitrogen-free extract.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
8.1 pounds meadow hay and 10.8 pounds broom-corn seed	45.6	84.9	53.2	35.8	70.3
7 pounds meadow hay, 6.6 pounds broom-corn seed, and 6.6 pounds oats	30.5	97.7	33.8	34.0	70.9
8.3 pounds meadow hay and 7.7 pounds oats	48.7	96.7	49.7	57.0	72.0

As will be observed, the starch is much more thoroughly digested than the other carbohydrates. In all the experiments the values obtained for digestibility of the group, "nitrogen-free extract," were comparatively low. The authors attribute this to the presence of the material called "undetermined constituents," and advance the opinion that this material does not consist of carbohydrates though included in this group by the ordinary analytical methods. The thoroughness with which the different members of the carbohydrate group were digested by the horse and other farm animals is discussed in the following section.

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[a] Arch. Physiol. [Pflüger], 93 (1902), p. 98.

COMPARATIVE DIGESTIBILITY BY HORSES AND RUMINANTS.

In computing the digestible nutrients furnished by different feeding stuffs, it has been a common custom to use available data obtained from digestion experiments with farm animals without distinguishing between ruminants and nonruminants, although differences had been pointed out by a number of observers. The extended investigations of Wolff[a] and his associates on the comparative digestive power of horses and sheep furnished much information on the subject. Dietrich and König[b] summarized the available data regarding the question and discussed it. The matter was also considered in the summary prepared by Jordan and Hall.[c]

The following table compares the coefficients of digestibility obtained with ruminants (chiefly sheep) and horses, the values given being the average of a large number of European and American experiments.

TABLE 4.—*Comparison of digestibility of a number of different feeding stuffs by ruminants and horses.*

Feeding stuffs.	Number of experiments.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.
Meadow hay:		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Ruminants	178	58.6	53.6	63.5	60.9
Horses	30	57.1	20.7	56.7	39.7
Difference in favor of ruminants	....	1.5	32.9	6.8	21.2
Timothy hay:					
Ruminants	6	48.1	52.7	64.0	46.6
Horses	2	21.2	47.3	47.3	42.6
Difference	....	26.9	5.4	16.7	4.0
Red-clover hay:					
Ruminants	56	58.6	57.2	65.7	50.0
Horses	5	55.7	28.7	63.5	37.4
Difference	....	2.9	28.5	2.2	12.6
Alfalfa hay:					
Ruminants	32	72.7	48.8	66.6	43.7
Horses	12	74.6	19.1	70.2	39.0
Difference	....	−1.9	29.7	−3.6	4.7
Wheat straw:					
Ruminants	3	23.4	35.6	38.7	55.5
Horses	6	27.7	65.7	28.1	17.7
Difference	....	−4.3	−30.1	10.6	37.8
Ground corn shives:					
Ruminants	9	46.7	78.2	60.4	57.0
Horses	2	67.5	59.8	47.0	54.6
Difference	....	−20.8	18.4	13.4	2.4
Oats:					
Ruminants	19	79.0	84.9	76.3	30.2
Horses	36	79.6	72.1	75.8	29.7
Difference	....	−0.6	12.8	0.5	0.5

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[a] Loc. cit., p. 60.

[b] Zusammensetzung und Verdaulichkeit der Futtermittel, 2. ed., vol. 2, pp. 1070, 1128.

[c] U S. Dept. Agr., Office of Experimental Stations Bul. 77.

TABLE 4.—*Comparison of digestibility of a number of different feeding stuffs by ruminants and horses*—Continued.

Feeding stuffs.	Number of experiments.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.
Corn meal:		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Ruminants	13	71.1	92.4	94.3	53.8
Horses	4	76.0	67.1	93.9	20.2
Difference	....	−4.9	25.3	0.4	33.6
Field beans:					
Ruminants	18	88.1	86.7	91.6	71.9
Horses	5	85.9	13.2	93.6	65.4
Difference	....	2.2	73.5	−2.0	6.5
Potatoes:					
Ruminants	11	56.1	2.4	90.3	....
Horses	1	88.0	....	99.4	9.1
Difference	....	−31.9	2.4	−9.1	−9.1

As it will be seen in nearly every case the ruminants digested a larger percentage of fat, carbohydrates, and crude fiber than horses, the differences being most marked in the case of the crude fiber. These results, are, it seems fair to say, in accord with what might be expected from differences in the digestive organs of the different classes of animals. The ruminants have an opportunity to chew their food more thoroughly than horses and retain it longer in the digestive tract. It is said that on an average horses retain their food 4 days or less; cattle, 3 or 4 to 7 or 8 days; sheep or goats from 3 or 4 days with ordinary rations to 7 or 8 days when straw is eaten. That the food is actually more finely divided by ruminants in chewing and digesting is indicated by the mechanical condition of the feces; those from horses containing an abundance of fairly large fragments of hay and other coarse fodders, etc., while the feces of cattle commonly contain undigested residue in a finer state of division. In the case of sheep the feces contain the undigested residue in still smaller fragments. It is well known that fineness of division is an important factor in considering the thoroughness of digestion. The length of time any given food material remains in the digestive tract is also important. It is perhaps generally believed that crude fiber is chiefly digested by the action of bacteria in the intestine and it is obvious that the longer materials remain in the intestine the greater the opportunity for the action of such micro-organisms.

Weiser and Zalischek,[a] in their investigation of the digestibility of the different constituents of the carbohydrate group, report results obtained with a horse and other farm animals. In nearly every case the rations were made up of different combinations of meadow hay, broom-corn seed, and oats. It is interesting to compare the average digestibility by different farm animals of the constituents into which the carbohydrate group was divided. In the case of pentosans a steer digested on an average 63.4, sheep 53.6, horse 45.5, and swine 47.9 per cent. In the case of crude fiber the values were, steer 56, sheep 55.1, horse 40.6, and swine 22.8 per cent. The values for starch were, for a steer 96.6, sheep 89.4, horse 93.1, and swine 98.3. The values for the undetermined constituents were, for a steer 44.8, sheep 32.9, horse 42.3, and swine 28 per cent, and for total nitrogen-free extract, steer 74.7, sheep 68.5, horse 71.1, and swine 85.6 per cent. As will be observed the horse, generally speaking, digested different carbohydrates less thoroughly than the ruminants but more thoroughly than the swine.

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[a] Loc. cit.

The fact that, other things being equal, horses digest their feed less thoroughly than cattle, i. e., retain less nutritive material from any given ration when it passes through the digestive tract, has been long recognized. For this reason horse manure is richer than manure from cattle. In other words, the horse manure contains a larger proportion of the ration than cow manure, and hence, more of the nitrogen and mineral matter, especially phosphoric acid and potash, originally present in the ration. Investigations carried on by I. P. Roberts, G. C. Watson, and others at the New York Cornell Station[a] have to do with this subject.

The value of the manure produced by horses was studied by Armsby[b] at the Pennsylvania Station. Observations made with a number of horses indicate that a horse produces annually about 12,700 pounds of fresh manure, not including the amount dropped while at work. This quantity, which would be worth about $13.50 as fertilizer, would require the use of about 2,500 pounds of straw for bedding. According to the author's calculations a ton of wheat straw economically used for bedding horses may result in 6 tons of fresh manure, although in general practice the amount is not likely to exceed 5 tons and may be much less if few animals are kept or the manure is infrequently removed.

RATIONS ACTUALLY FED AND FEEDING STANDARDS.

The amount of the different feeding stuffs required and hence the quantity of nutrients supplied to horses may be learned by observation or experiment or a combination of the two methods. Doubtless all practical horse feeders supply rations which they believe are suited to their horses' needs, and in stables where horses are fed in any considerable number economy demands that the amount fed shall be fixed and not vary according to the wishes of the feeder. When the feeding stuffs used are weighed and the condition of the horses is noted, a feeding experiment results. Using average values obtained from many more or less complicated feeding experiments and other investigations, so-called feeding standards have been devised which are designed to show the amount of the different nutrients required per day for various conditions of work and rest. For the sake of uniformity, the standards are usually calculated on the uniform basis of 1,000 pounds live weight. The feeding standards show the amount of protein, fat, and carbohydrates required daily, and often the nutritive ratio also; that is, the ratio of protein to the sum of the carbohydrates and 2.25 times the fat. It is also possible to express the feeding standards in terms of protein and energy, since the functions of food, as previously stated, are to build and repair tissue and supply energy, protein alone serving for the former purpose, while all the nutrients yield energy. The best known feeding standards for horses and other farm animals are those computed by Wolff and revised by Lehmann.

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[a] See especially New York Cornell Station Bul. 56, p. 169.

[b] Pennsylvania Station Rpt. 1892, p. 79.

Very frequently so-called standards for horses have been proposed which have shown the quantities of feeding stuffs required; for instance, the pounds of oats and hay needed per day per 1,000 pounds live weight. Such standards, or more properly standard rations, have been adopted in many countries for army horses, and in other cases where large numbers of horses are fed under uniform conditions. The digestible nutrients furnished by such standard rations can be calculated by the aid of figures showing the average composition and digestibility of the feeding stuffs. Such calculations have been often made, especially by earlier investigators, on the basis of data secured by digestion experiments with ruminants. However, this method can not give the most satisfactory results. If possible, coefficients of digestibility obtained in experiments with horses should be used.

Standard rations and feeding standards have been proposed by Grandeau and Leclerc, Lavalard, and others. These French investigators based their recommendations chiefly on investigations with the horses of the Paris cab companies and the French army. The work extended over a number of years and thousands of horses were included. In connection with the work the digestibility of the ration was determined.

In compiling this bulletin letters were addressed to express companies, cab companies, fire companies, and other organizations in different cities of the United States using large numbers of horses, requesting information regarding the rations fed. Information was also secured regarding the average weight of the horses. Similar values regarding horses fed by a number of cab companies, etc., in foreign countries were compiled from available published data. The rations fed army horses in the United States and other countries were also learned by correspondence and by compilation from various sources and included for purposes of comparison as were also data regarding the rations fed in a large number of experiments carried on at the experiment stations in this country, only those tests being selected in which the horses maintained their weight.

No attempt has been made to gather statistics regarding race horses, hunters, fancy coach and driving horses, and similar animals, as the main purpose of the table was to learn the value of the rations fed farm and other work horses in this country. The table below shows the nutrients furnished per 1,000 pounds live weight by these rations and also the calculated digestible nutrients and the total energy supplied by them. In most cases the values for digestible nutrients were calculated by the aid of coefficients of digestibility obtained in experiments with horses and referred to on a preceding page (41). From the data thus collected the average quantities of nutrients furnished by the rations of horses performing like amounts of work were calculated. For purposes of comparison the Wolff-Lehmann feeding standards are also included in the table as well as standards or averages proposed by Lavalard and a number of other investigators.

TABLE 5.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight.*

	Weight of horses.	Rations actually fed.	Nutrients in ration per 1,000 pounds live weight.				Digestible nutrients in ration per 1,000 pounds live weight.				Energy in digestible nutrients.
			Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
ARMY HORSES.											
	Lbs.	*Pounds.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
United States:											
Cavalry	1,050	Oats, 12 Hay, 14	2.14	0.90	12.82	4.95	1.25	0.57	8.00	1.97	23,300
Artillery	1,125	Oats, 12 Hay, 14	2.00	.84	11.96	4.62	1.16	.53	7.48	1.84	21,750
Mules	1,025	Oats, 9 Hay, 14	1.84	.78	11.39	4.80	1.00	.48	6.88	1.94	20,250
Great Britain:											
In quarters	1,125	Oats, 10 Hay, 12 Straw, 8	2.16	.81	12.42	6.23	1.38	.41	7.32	1.79	21,400
In camp	1,125	Oats, 12 Hay, 12	2.11	.80	10.76	3.80	1.47	.43	7.35	1.38	20,750
Cabs	1,125	Oats, 10 Hay, 12	1.92	.71	9.72	3.61	1.32	.36	6.57	1.32	18,650
With extra issue	1,125	Oats, 12 Hay, 12 Straw, 8	2.35	.92	13.46	6.42	1.53	.51	8.11	1.84	23,500
Mules (heavy work).	1,025	Oats, 10 Hay, 12 Straw, 8	2.37	.92	13.63	6.84	1.51	.49	8.04	1.96	23,450
Mules in camp	1,025	Oats, 12 Hay, 12	2.31	.88	11.81	4.17	1.61	.47	8.27	1.51	22,750
Small mules	850	Oats, 5 Hay, 10 Straw, 13	2.22	.86	14.24	9.21	1.26	.44	7.14	2.33	21,800
Small mules in camp.	850	Oats, 6 Hay, 12	2.04	.71	10.12	4.28	1.34	.32	6.60	1.60	19,050
Registered horses	1,125	Oats, 18 Hay, 10	2.52	1.02	13.12	3.92	1.83	.61	9.28	1.37	25,800

TABLE 5.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight*—Continued.

	Weight of horses.	Rations actually fed.	Nutrients in ration per 1,000 pounds live weight.				Digestible nutrients in ration per 1,000 pounds live weight.				Energy in digestible nutrients.
			Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
ARMY HORSES—cont'd.											
France:											
Peace footing, maintenance ration—	*Lbs.*	*Pounds.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
Reserve	1,050	Oats, 13.01 Hay, 8.82	2.09	0.83	10.81	3.41	1.50	0.49	7.56	1.21	21,150
Line	1,050	Oats, 11.46 Hay, 7.72	1.84	.73	9.50	2.99	1.31	.43	6.65	1.06	18,550
Light cavalry	850	Oats, 10.36 Hay, 6.61	2.01	.80	10.42	3.24	1.45	.47	7.32	1.14	20,400
Artillery and train.	1,075	Oats, 12.35 Hay, 8.49	1.94	.77	10.07	3.19	1.39	.45	7.03	1.13	19,650
Mules	950	Oats, 10.8 Hay, 7.5	1.94	.77	9.99	3.18	1.38	.44	6.98	1.13	19,500
War footing, maintenance ration—											
Reserve	1,050	Oats, 14.7 Hay, 8.82	2.27	.90	11.75	3.58	1.63	.54	8.28	1.26	23,050
Line	1,050	Oats, 13.54 Hay, 7.72	2.05	.83	10.65	3.20	1.48	.50	7.52	1.12	20,900
Light cavalry	850	Oats, 11.76 Hay, 6.61	2.19	.88	11.39	3.41	1.59	.54	8.05	1.19	22,400
Artillery and train.	1,075	Oats, 14.2 Hay, 8.49	2.13	.86	11.07	3.38	1.53	.51	7.80	1.18	21,700
Germany:											
Heavy ration—											
Garrison	1,050	Oats, 11.16 Hay, 5.58 Straw, 7.81	1.88	.80	11.29	5.19	1.25	.50	6.81	1.33	19,550
March	1,050	Oats, 12.27 Hay, 3.34 Straw, 3.9	1.66	.72	9.59	3.41	1.19	.48	6.36	.93	17,800
Field	1,050	Oats, 12.61 Hay, 3.34 Straw, 3.9	1.70	.74	9.77	3.45	1.22	.49	6.50	.94	18,150
Light cavalry in garrison.	1,050	Oats, 10.6 Hay, 5.58 Straw, 7.81	1.83	.77	10.97	5.13	1.21	.48	6.57	1.31	18,950
Light cavalry on march.	1,050	Oats, 11.5 Hay, 3.34 Straw, 3.9	1.58	.70	9.15	3.33	1.13	.46	6.04	.90	16,950
Light cavalry in field.	1,050	Oats, 12.61 Hay, 3.34 Straw, 3.39	1.69	.73	9.58	3.27	1.21	.49	6.45	.90	17,950
Light ration—											
Garrison	1,050	Oats, 9.48 Hay, 5.58 Straw, 7.81	1.70	.71	10.35	5.03	1.10	.44	6.11	1.29	17,650
March	1,050	Oats, 10.6 Hay, 3.34 Straw, 3.9	1.50	.65	8.66	3.24	1.07	.42	5.66	.88	15,900
Field	1,050	Oats, 11.16 Hay, 3.34 Straw, 3.9	1.54	.68	8.97	3.30	1.10	.44	5.90	.89	16,550
OMNIBUS HORSES.											
France:											
Paris, 1879	1,240	Beans, 1.4 Corn, 6.9 Oats, 10.1 Hay, 9.1 Straw, 10.5	2.61	.81	16.44	5.19	1.73	.44	10.55	1.43	27,350
Paris, 1880	1,240	Beans, 1.4 Corn, 8.3 Oats, 8.8 Hay, 7.8 Straw, 11.1	2.52	.76	16.41	4.97	1.65	.42	10.60	1.31	27,000

Table 5.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight*—Continued.

	Weight of horses.	Rations actually fed.	Nutrients in ration per 1,000 pounds live weight.				Digestible nutrients in ration per 1,000 pounds live weight.				Energy in digestible nutrients.
			Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
OMNIBUS HORSES—continued.	*Lbs.*	*Pounds.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
France—Continued.											
Paris, 1884	1,240	Beans, 1.4 Bran, 0.9 Corn, 8.5 Oats, 8.7 Hay, 8.5 Straw, 8.7	2.65	0.78	16.18	4.64	1.75	0.43	10.82	1.28	27,550
Paris, 1885	1,240	Beans, 0.9 Bran, 0.8 Corn, 11.3 Oats, 6.2 Hay, 8.5 Straw, 8.4	2.49	.69	16.26	4.38	1.58	.36	11.09	1.20	27,350
Paris, 1886	1,240	Beans, 0.1 Bran, 0.5 Corn, 13 Oats, 5.5 Hay, 8.6 Straw, 7.3	2.32	.68	16.06	4.04	1.43	.34	11.22	1.11	27,000
Paris, 1887	1,240	Corn, 10.8 Oats, 8.1 Hay, 8.7 Straw, 8.2	2.33	.73	16.16	4.41	1.44	.40	10.98	1.22	27,050
Average							**1.60**	**.40**	**10.88**	**1.26**	**27,220**
STREET-CAR HORSES.											
Great Britain:											
London	1,150	Corn, 7 Oats, 3 Peas, 3 Hay, 12 Straw, 1	1.87	.42	9.52	1.91	1.23	.15	7.01	.90	17,650
Liverpool	1,150	Beans, 4 Corn, 12 Bran, 1 Hay, 14	2.55	.45	11.52	2.74	1.72	.13	8.95	1.04	22,380
Glasgow	1,150	Corn, 11 Oats, 6 Bran, 0.5 Hay, 8.5 Straw, 1	1.73	.50	10.66	2.24	1.11	.25	8.13	.73	19,590
Dublin	1,150	Corn, 14 Oats, 3 Bran, 0.5 Hay, 12	1.91	.49	11.60	2.46	1.16	.19	9.01	.87	21,360
Various European cities:											
Bremen	1,150	Corn, 14.3 Oats, 2.2 Peas, 1.1 Hay, 8.8 Straw, 2.2	1.81	.43	11.46	2.27	1.11	.17	8.80	.71	20,480
Brussels	1,150	Corn, 7.7 Oats, 11 Hay, 4.4 Straw, 3.3	1.62	.57	10.44	2.26	1.10	.35	7.64	.64	18,930
Bordeaux, winter	1,150	Corn, 15.4 Hay, 13.2 Straw, 1.1	1.82	.42	11.61	2.64	1.04	.13	8.87	.91	20,700
Bordeaux, summer	1,150	Corn, 11 Oats, 4.4 Hay, 13.2 Straw, 1.1	1.86	.51	11.23	2.90	1.13	.22	8.33	1.01	20,430
Hamburg	1,150	Corn, 17.6 Oats, 1.7 Hay, 7.7 Straw, 4.4	1.80	.44	12.84	2.48	1.03	.19	9.70	.69	22,030

TABLE 5.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight*—Continued.

	Weight of horses.	Rations actually fed.	Nutrients in ration per 1,000 pounds live weight.				Digestible nutrients in ration per 1,000 pounds live weight.				Energy in digestible nutrients.
			Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
STREET CAR HORSES—continued.											
Various European cities—Continued.	*Lbs.*	*Pounds.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
Munich	1,150	Corn, 6.6 Oats, 11 Hay, 5.5 Straw, 4.4	1.64	0.58	10.59	2.64	1.11	0.35	7.46	0.74	18,800
Vienna	1,150	Oats, 15.4 Hay, 11 Straw, 2.2	1.84	.73	10.02	3.39	1.29	.43	6.55	1.13	18,490
Average			**1.86**	**.54**	**11.05**	**2.54**	**1.18**	**.23**	**8.22**	**.85**	**20,075**
HORSES WITH LIGHT WORK.											
Driving horse, Wyoming station.	1,200	Alfalfa, 21.25 Straw, 3.2	2.38	.18	5.87	2.34	1.76	.05	3.58	.92	11,855
Carriage horse	1,050	Oats, 10 Hay, 12	2.06	.76	10.42	3.87	1.40	.40	6.97	1.41	19,935
Average			**2.22**	**.47**	**8.15**	**3.10**	**1.58**	**.22**	**5.27**	**1.18**	**15,895**
Fire company horses:											
Boston, Mass	1,400	Ground grain, 9.38. Hay, 18	1.65	.68	9.57	4.57	.87	.41	6.14	1.73	18,000
Chicago, Ill	1,350	Oats, 4 Hay, 15	1.00	.43	6.77	3.50	.42	.24	3.70	1.45	11,365
Portland, Me	1,350	Oats, 6 Hay, 10	.96	.41	5.99	2.57	.52	.25	3.59	1.04	10,650
Albany, N. Y	1,350	Oats, 12 Hay, 12 Straw, 10	1.58	.67	9.30	3.42	.95	.42	5.91	1.35	17,050
St. Lous, Mo	1,350	Oats, 10 Bran, 2.5 Hay, 7	1.46	.58	7.76	2.38	.99	.39	5.16	.90	14,700
New York, N. Y	1,350	Oats, 12 Hay, 9	1.44	.62	8.30	2.78	.92	.40	5.45	1.07	15,550
Average			**1.35**	**.56**	**7.95**	**3.20**	**.78**	**.35**	**4.99**	**1.26**	**14,555**
General average for light work.			**1.57**	**.54**	**8.00**	**3.18**	**.99**	**.32**	**5.06**	**1.24**	**14,890**
HORSES WITH MODERATE WORK.											
Express horses:											
Richmond, Va., summer.	1,400	Corn, 4.67 Oats, 5.33 Bran, 0.83 Corn meal, 4.16 Hay, 15	1.79	.78	11.78	3.64	.97	.45	8.19	1.46	21,650
Richmond, Va., winter.	1,400	Corn, 4.38 Oats, 7.5 Bran, 0.83 Corn meal, .164 Hay, 16	2.00	.86	12.88	3.99	1.12	.50	8.93	1.59	23,750
Jersey City	1,325	Corn, 2 Oats, 19 Bran, 1.5 Hay, 9.5	2.45	1.03	13.45	3.57	1.66	.67	9.37	1.32	25,800
Boston	1,325	Corn, 12 Oats, 5.25 Hay, 20	2.38	1.04	14.96	5.32	1.28	.60	9.75	2.12	27,000
Average			**2.15**	**.93**	**13.27**	**4.13**	**1.26**	**.55**	**9.06**	**1.62**	**24,550**

TABLE 5.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight*—Continued.

	Weight of horses.	Rations actually fed.	Nutrients in ration per 1,000 pounds live weight.				Digestible nutrients in ration per 1,000 pounds live weight.				Energy in digestible nutrients.
			Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
HORSES WITH MODERATE WORK—cont'd.											
Cab horses, United States.	*Lbs.*	*Pounds.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
New York, N. Y	1,200	Oats, 14 Hay, 10	1.87	0.79	10.72	3.53	1.20	0.53	7.06	1.37	20,100
Philadelphia, Pa	1,200	Corn, 17 Oats, 9.28 Groundgrain. 4.40.[a] Hay, 13.50 Straw, 7.10	2.01	.82	12.13	4.13	1.19	.50	8.05	1.64	22,350
Washington, D.C.	1,200	Oats, 10 Corn, 5 Hay, 23	2.56	1.12	16.50	6.43	1.28	.63	10.42	2.60	29,250
Do	1,350	Oats, 12 Hay, 12	1.58	.67	9.30	3.42	.95	.42	5.91	1.35	17,050
San Francisco, Cal.	1,350	Oats, 8 Hay, 16	1.39	.59	8.87	4.00	.70	.36	5.21	1.64	15,550
Average			**1.88**	**.80**	**11.51**	**4.30**	**1.06**	**.49**	**7.33**	**1.72**	**20,860**
Farm horses:											
Wyoming Station	1,000	Alfalfa, 13.75 Straw, 2.25	1.85	.14	6.27	......	1.37	.03	4.03	......	8,240
New Hampshire Station.	1,235	Bran, 2 Corn, 6 Gluten meal, 6 Hay, 10	2.37	.93	10.49	2.90	1.59	.64	7.47	1.03	21,465
Do	1,220	Bran, 2 Corn, 6 Oats, 8 Hay, 10	2.03	.86	11.92	3.26	1.21	.50	8.18	1.24	21,880
Do	1,230	Hay, 10 Bran, 7 Corn, 8	2.03	.78	11.21	3.00	1.18	.41	7.65	1.14	20,275
Do	1,220	Corn, 8 Linseed meal, 4 Hay, 10	2.35	.66	9.46	2.80	1.52	.36	6.64	1.24	19,000
Do	1,250	Bran, 2 Corn, 8 Cotton-seed meal, 1. Hay, 10	1.73	.71	9.11	2.65	.98	.39	6.18	1.05	16,915
Do	1,170	Bran, 2 Corn, 6 Oats, 8 Hay, 10	2.11	.90	12.43	3.41	1.27	.44	8.53	1.29	22,485
Do	1,280	Bran, 7 Corn, 8 Hay, 10	1.96	.75	10.80	2.89	1.14	.40	7.36	1.10	19,545
Do	1,290	Corn stover, 6 Hay, 6 Corn, 7 Oats, 4 Bran, 3	1.74	.71	10.44	2.88	1.05	.40	7.59	1.40	20,360
Do	1,230	Hay, 12 Oats, 7 Corn, 7	1.85	.84	11.75	3.50	1.01	.46	8.14	1.37	21,510
Do	1,300	Corn stover, 12 Oats, 7 Corn, 7	1.56	.66	9.87	2.45	1.04	.40	7.72	1.49	21,005
Do	1,175	Corn stover, 12 Bran, 7 Corn, 7	1.94	.67	10.57	2.67	1.30	.39	8.07	1.63	22,105
Do	1,280	Hay, 12 Bran, 7 Corn, 7	1.98	.75	10.97	3.33	1.11	.40	7.38	1.30	19,900

[a] Corn meal and bran, 3.07: 1.33.

TABLE 5.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight*—Continued.

	Weight of horses.	Rations actually fed.	Nutrients in ration per 1,000 pounds live weight.				Digestible nutrients in ration per 1,000 pounds live weight.				Energy in digestible nutrients.
			Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
HORSES WITH MODERATE WORK—cont'd.	*Lbs.*	*Pounds.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
Farm horses—cont'd.											
New Hampshire Station.	1,275	Hay, 12 Corn, 7 Oats, 4 Bran, 3	1.87	0.78	11.20	3.36	1.03	0.42	7.66	1.31	20,370
Do	1,340	Hay, 12 Corn, 7 Oats, 7	1.70	.77	10.78	3.21	.93	.42	7.47	1.25	19,620
New Jersey Station	1,000	Hay, 6 Bran, 2 1/7 Corn, 4 2/7 Dried brewers' grain, 8 4/7.	3.21	.89	10.81	3.09	2,22	.65	6.99	1.38	22,440
Do	1,000	Hay, 6 Bran, 2 1/7 Corn, 4 2/7 Oats, 8 4/7	2.23	.89	12.11	2.68	1.45	.56	8.65	1.00	23,010
Do	1,150	Hay, 8 Corn meal, 6.25 Dried brewers' grain, 6.15.	2.24	.65	9.55	2.82	1.49	.48	6.53	1.24	19,250
Do	1,180	Hay, 8 Corn meal, 6.55 Linseed meal, 5.40.	2.61	.49	8.81	2.45	1.88	.35	6.60	1.17	19,425
Massachusetts Station.	1,100	Hay, 18 Wheat bran, 2. Provender, 6 = crushed corn, 2.73; oats, 3.27.	1.85	.76	11.85	5.25	.85	.41	7.04	2.14	20,385
Do	1,100	Hay, 20 Wheat bran, 2. Provender, 6 = crushed corn, 2.73; oats, 3.27.	1.96	.81	12.66	5.77	.87	.44	7.43	2.37	21,705
Do	1,080	Hay, 15 Wheat bran, 2. Provender, 4 = crushed corn, 1.73; oats, 2.27.	1.53	.60	9.62	4.43	.70	.32	5.58	1.81	16,200
Do	1,090	Hay, 15 Wheat bran, 3. Provender, 6 = crushed corn, 2.73; oats, 3.27.	1.85	.73	11.21	4.58	.94	.41	6.85	1.85	19,660
Utah Station	1,125	Timothy hay, 25.8. Corn, 23.7	3.12	1.30	26.06	7.05	1.43	.61	18.60	2.68	44,815
Do	1,200	Clover hay, 26.1. Oats, 11.8 Wheat, 11.8	4.96	1.10	21.67	7.03	3.35	.60	15.36	2.53	42,040
Do	1,125	Clover hay, 22.4. Oats, 9.7 Wheat, 9.7	4.44	.98	19.33	6.39	3.00	.53	13.67	2.30	36,520
Do	1,200	Timothy hay, 22.4. Corn, 19.4	2.44	1.01	20.50	5.70	1.10	.48	14.51	2.18	35,115
Do	1,400	Alfalfa hay, 24.5. Bran and shorts (1:1), 10.	3.59	.69	11.43	4.96	2.71	.28	7.99	1.88	24,580

TABLE 5.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight*—Continued.

	Weight of horses.	Rations actually fed.	Nutrients in ration per 1,000 pounds live weight.				Digestible nutrients in ration per 1,000 pounds live weight.				Energy in digestible nutrients.
			Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
HORSES WITH MODERATE WORK—cont'd.	*Lbs.*	*Pounds.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
Farm horses—cont'd.											
Utah Station	1,370	Alfalfa hay, 25. Bran and shorts (1:1), 10.	3.72	0.71	11.83	5.16	2.81	0.29	8.27	1.96	25,480
Do	1,325	Timothy hay, 22.8. Bran and shorts (1:1), 10.	2.17	.75	11.93	5.61	1.11	.42	6.56	2.31	20,345
Do	1,420	Timothy hay, 23.5. Bran and shorts (1:1), 12.2.	2.28	.78	12.20	5.51	1.23	.44	6.82	2.25	21,015
Do	1,400	Alfalfa hay, 24.5. Bran and shorts (1:1), 12.2.	3.82	.75	12.29	5.09	2.89	.31	8.58	1.91	26,615
Do	1,400	Alfalfa hay, 25. Bran and shorts (1:1), 14.6.	4.14	.83	13.39	5.32	3.14	.38	9.36	1.99	28,555
Do	1,120	Alfalfa hay, 16. Bran and shorts (1:1), 12.6.	3.75	.79	12.32	3.96	2.86	.38	8.60	1.45	25,615
Do	1,230	Timothy hay, 13.7. Oats, 12.	1.81	.76	10.84	4.15	1.06	.48	6.79	1.65	19,700
Do	1,235	Alfalfa hay, 14.7. Oats, 11.5.	2.80	.72	10.65	4.66	2.15	.38	7.79	1.42	22,715
Do	1,385	Alfalfa hay, 19.7.	2.04	.31	6.07	3.56	1.52	.06	4.26	1.39	16,435
Do	1,385	Alfalfa hay, 19.9.	2.06	.32	6.14	3.59	1.54	.06	4.31	1.40	13,740
Do	1,420	Alfalfa hay, 32.6.	3.28	.51	9.80	5.74	2.45	.10	6.88	2.24	21,940
Virginia Station	1,460	Hay, 19.3 Corn, 11.3 Corn silage, 23.1.	1.95	.92	13.70	4.92	.81	.49	9.18	2.25	24,815
Do	1,155	Hay, 16 Corn, 14.1	2.10	1.00	14.73	4.28	.92	.48	10.44	1.71	26,335
Average			**2.46**	**.75**	**11.92**	**4.05**	**1.57**	**.40**	**8.09**	**1.62**	**22,760**
General average for moderate work.			**2.38**	**.77**	**11.99**	**4.08**	**1.49**	**.42**	**8.09**	**1.63**	**22,710**
Farm mules, Virginia Station.	1,310	Hay, 15.2 Corn, 10.5 Corn silage, 10.5.	1.70	.82	12.00	4.00	.72	.42	8.22	1.75	21,655
Do	1,190	Hay, 14.5 Corn, 9 2	1.54	.72	10.86	3.70	.62	.34	7.34	1.50	19,030
Do	1 020	Hay, 9.8 Corn, 6.1 Corn silage, 12.2.	1.46	.69	10.29	3.61	.61	.36	6.96	1.65	18,670

TABLE 5.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight*—Continued.

	Weight of horses.	Rations actually fed.	Nutrients in ration per 1,000 pounds live weight.				Digestible nutrients in ration per 1,000 pounds live weight.				Energy in digestible nutrients.
			Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
HORSES WITH MODERATE WORK—cont'd.	*Lbs.*	*Pounds.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
Farm mules, Virginia Station.	1,080	Hay, 13.4 Corn, 11.8	1.88	0.90	13.18	3.83	0.82	0.44	9.34	1.54	23,510
Do	1,275	Hay, 15.6 Corn, 10.5 Corn silage, 14.6.	1.84	.88	12.96	4.38	.78	.46	8.84	1.96	23,480
Do	1,225	Hay, 11.7 Corn, 9.9	1.41	.67	9.93	2.94	.61	.32	7.00	1.18	17,700
Average			**1.64**	**.78**	**11.54**	**3.74**	**.69**	**.39**	**7.95**	**1.60**	**20,675**
HORSES WITH SEVERE WORK.											
Truck and draft horses:											
Chicago, Ill., daily ration.	1,500	Oats, 7.5 Hay, 20	1.38	.58	8.99	4.34	.64	.34	5.11	1.79	15,450
Chicago, Ill., holiday ration.	1,500	Oats, 2 Bran, 2.5 Oil meal, 0.2 Hay, 20	1.25	.47	7.74	4.16	.53	.26	4.11	1.75	13,000
South Omaha, Nebr.	1,500	Oats, 15 Hay, 12	1.65	.70	9.57	3.27	1.04	.45	6.23	1.27	17,800
New York, N. Y.	1,600	Oats, 23 Hay, 12	2.14	.91	11.96	3.54	1.44	.61	8.10	1.33	22,800
Washington, D. C., summer.	1,600	Oats, 19 Hay, 13	1.88	.79	10.74	3.49	1.21	.53	7.11	1.34	20,200
Washington, D. C., winter.	1,600	Oats, 12.5 Corn, 6.75 Ground grain,[a] 4. Hay, 10	1.93	.81	11.19	2.83	1.25	.51	8.16	1.03	21,550
Average (omitting holiday ration).			**1.80**	**.76**	**10.49**	**3.49**	**1.12**	**.49**	**6.94**	**1.35**	**19,560**
Draft horses, heavy, hard work. Sidney's estimate.	2,000	Beans, 6 Oats, 13 Corn, 3 Clover, 15	3.87	.75	11.72	3.11	1.94	.28	5.86	1.56	18,590
FARM HORSES, SETTEGAST'S ESTIMATE.											
Light work	1,250	Oats, 8 Hay, 7.5 Straw, 3	1.29	.50	7.45	2.83	.87	.29	4.61	.91	13,100
Moderate work	1,250	Oats, 10 Hay, 10 Straw, 3	1.64	.63	9.23	3.50	1.11	.35	5.80	1.17	16,500
Heavy work	1,250	Oats, 13 Hay, 12 Straw, 3	2.04	.79	11.31	4.16	1.40	.45	7.24	1.40	20,550
FEEDING STANDARDS AND AVERAGE RATIONS.											
Light work, Wolff-Lehmann.							1.5	.40	9.5		22,150
Medium work, Wolff-Lehmann.							2.0	.60	11.0		26,700
Heavy work, Wolff-Lehmann.							2.5	.80	13.3		32,750

[a] Bran, cornmeal, and cut hay 2 : 1.6 : 4.

TABLE 5.—*Rations actually fed to horses and digestible nutrients and energy in rations calculated to basis of 1,000 pounds live weight*—Continued.

	Weight of horses.	Rations actually fed.	Nutrients in ration per 1,000 pounds live weight.				Digestible nutrients in ration per 1,000 pounds live weight.				Energy in digestible nutrients.
			Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	
FEEDING STANDARDS AND AVERAGE RATIONS—continued.	*Lbs.*	*Pounds.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Calories.*
Maintenance, moderate work, original, Grandeau.	......	....	......	......	......	......	2.14	.52	11.15		26,900
Maintenance, moderate work, modified, Grandeau.	......	....	......	......	......	......	1.95	.44	9.93		23,950
Paris Bus Co., horses, Lawes & Gilbert's computation.	......	....	......	......	......	......	1.60	.40	12.14		27,200
Ordinary work, Lavalard.	......	....	......	......	......	......	1.10		[a] 11.0		22,510
Severe work, Lavalard.	......	....	......	......	......	......	1.30		[a] 11.0		22,880
AMERICAN EXPERIMENTS.											
Horses with light work:											
Driving horses	......	....	......	......	......	......	1.58	.22	5.27	1.18	15,895
General average	......	....	......	......	......	......	.99	.32	5.06	1.24	14,890
Horses with moderate work:											
Express and cab horses.	......	....	......	......	......	......	1.06	.49	7.33	1.72	20,860
Farm horses	......	....	......	......	......	......	1.57	.40	8.09	1.62	22,760
General average	......	....	......	......	......	......	1.49	.42	8.09	1.63	22,710
Mules with moderate work: Farm mules.	......	....	......	......	......	......	.69	.39	7.95	1.60	20,675
Horses with severe work: Truck and draft horses.	......	....	......	......	......	......	1.12	.49	6.94	1.35	19,560

[a] This value represents total carbohydrates plus 2.25 times the fat.

The figures in the above table, showing the amounts eaten by army horses in the United States and other countries and by horses belonging to cab companies, etc., in foreign countries, were compiled from various sources, though in many cases the data have been recalculated, using, as previously noted, the values for composition and digestibility included in Tables 1 and 2. These figures are included chiefly for purposes of comparison with those showing the nutrients and energy in the ration of American work horses, especially those used by cab companies, express companies, and other private firms, and by farmers in different regions of the United States.

It will be noticed that the number of feeding stuffs used in making up the rations fed is not large, oats and corn being the common grains, and hay, usually timothy, the common coarse fodder. The amounts of nutrients and energy in the different rations of the horses making up the different groups varied within rather wide limits, which is not surprising when it is remembered that the horses were fed under many different conditions and by a large number of feeders whose opinions regarding what constituted a proper ration naturally differed. Taken as a whole it does not seem unfair to assume that the figures are reasonably trustworthy, since it is highly probable that the private firms fed their horses rations which experience had shown were satisfactory and in the case of the farm horses, which were without exception fed at the experiment stations under controlled conditions, the rations were undoubtedly adequate, since the only results included are those of feeding tests in which the horses maintained their weight. As will be seen, the average values for the protein and energy in the rations of the horses performing light work are considerably less than similar values for horses performing moderate work. The data for the former group is much more limited than for the latter, but the relation is in accord with the commonly accepted theories. The farm mules consumed a ration furnishing less protein and practically the same amount of energy as horses performing similar work, though the tests with mules are too few for general deductions. The rations of the truck and draft horses performing severe muscular work furnished less protein and energy on an average than the rations of the horses with moderate work. This is not in accord with commonly accepted theories and may be explained in part perhaps by the fact that the data for the group performing severe work is much less extended than that for the group performing moderate work. There is every reason to suppose that the truck and draft horses received rations sufficient for their needs, as the firms owning them are known to make the effort to maintain their horses in good condition. Such truck and draft animals are often employed at work which is performed at a slow pace, and undoubtedly this has a bearing on the fact that they were able to perform a large amount of work on a comparatively small ration, as the speed at which work is performed has a marked effect upon the food requirements.

It will be seen that the average values, representing the amounts which were fed to American horses performing light, moderate, and severe work, differ somewhat from the commonly accepted feeding standards. The average values for horses at moderate work (express horses, cab horses, and farm horses), namely, 1.49 pounds digestible protein and 22,710 calories per 1,000 pounds live weight per day are considerably less than those called for by the Wolff-Lehmann standard or by Grandeau's estimates. The agreement with Lavalard's figures is much closer, the protein being a little larger and the energy very nearly the same. The average values for horses at light work, namely, 0.99 pound digestible protein and 14,890 calories per 1,000 pounds live weight, are also less than the values called for by the Wolff standard. The greatest difference, however, is observed in the values for horses with severe work, the American average being 1.12 pounds digestible protein and 19,560 calories. It would be going too far to propose the adoption of these average values as standards in the place of those which have been commonly accepted. It is undoubtedly true that a feeding standard should be based on other data than the results of feeding experiments; however, in so far as the results represent the average practice of successful feeders they are worthy of consideration, and certainly emphasize the importance of undertaking investigations with a view to revising the standards. It should be remembered that the amounts of digestible nutrients in the rations actually fed were calculated with the aid of coefficients of digestibility obtained with horses and are, therefore, considerably lower than would be the case if average values obtained with ruminants had been used, a method of calculation which has been often followed in the past, but which does not seem desirable.

METHOD OF CALCULATING RATIONS.

The feeding value of any ration may be readily calculated and compared with the standards. Suppose a horse at moderate work and weighing 1,200 pounds is fed 11 pounds of oats and 10 pounds of timothy hay daily. The Wolff-Lehmann feeding standard for horses at moderate work calls for 1.8 pounds of protein and 26,700 calories per thousand pounds live weight. A horse weighing 1,200 pounds would therefore require 1.2 times as much, or 2.2 pounds protein and 32,000 calories. Oats contain 9.39 pounds of digestible protein and 122,100 calories per hundred pounds. Eleven pounds would therefore furnish 1.03 pounds of protein (9.39 × 0.11 = 1.03), and 13,430 calories (122,100 × 0.11 = 13,430). Timothy hay furnishes 1.25 pounds protein and 69,850 calories per hundred pounds. Ten pounds would therefore furnish 0.13 pounds protein (1.25 × 0.10 = 0.13) and 6,985 calories (69,850 × 0.10 = 6,985). The sum of the nutrients furnished by 11 pounds of oats and 10 pounds of hay would therefore be 1.16 pounds protein and 20,415 calories, or 1.04 pounds protein and 11,585 calories less than the standard calls for. This may be made up by adding more oats, hay, or other feeding stuff. The amount of oats required to furnish the necessary protein may be learned from the proportion 100 : 9.39 : : x : 1.04; or, in other words, by dividing 1.04 by .0939, which gives 11.07. This quantity of oats would also furnish 13,517 calories, making the total protein of the ration 2.2 pounds and the total fuel value 33,932 calories. The fuel value of the ration is in excess of the standard, though the agreement is close enough for all practical purposes.

As previously stated, it is not necessary that the amounts furnished in a ration shall exactly equal those called for by the standard, but rather that they approximate them, being greater rather than less through a long period. Rations which will furnish the amounts called for by other feeding standards, or by the average values deduced from American rations, can, of course, be calculated in the same way. As will be noted, the amount of feeding stuffs necessary to provide nutrients equal to the amount called for by the Wolff standard for a horse at moderate work is large compared with the amounts ordinarily used in this country. (See discussion on pages 57, 58.)

MUSCULAR WORK AND ITS EFFECT ON FOOD REQUIREMENTS.

It is commonly said that the amount of food required by horses is proportionate to their weight; it being self-evident that a large horse would require more material than a small horse to build and repair the body and to carry on all the vital processes which constitute internal muscular work. Investigations have shown that the requirements are more nearly proportional to the surface areas than to the body weight. Individual peculiarity is, of course, a factor which must be reckoned with, but the general statement is justified. The factor which has the greatest influence on the ration required is the amount of work performed, the ration increasing with the work. When horses which have been consuming a large ration and performing work are compelled to rest, even for a few days, the ration should be diminished. Girard[a] found that the horses at the Meaux farm, doing hard work, were well nourished with a maximum ration of 16–20 liters (15–19 quarts) oats, 6.5 kilograms (14 pounds) hay, and straw ad libitum. If the work stopped for three days and the ration was not diminished the horses were subject to paralysis, resulting in death. It was therefore recommended that on Sundays and holidays the ration consist of 6 liters (5.7 quarts) oats at noon, and 6 liters (5.7 quarts) of bran mash night and morning, with the same amount of hay and straw as before. The disease practically ceased after this practice was followed. The facts brought out above are quite generally recognized by large feeders and it is a common custom to diminish the rations on Sundays and holidays.

In order to study the effects of work upon the amount of food required it is necessary to have some means of measuring and comparing the different kinds of work done.

MEASURING MUSCULAR WORK.

It has been said already that the total work performed by a horse consists of internal and external muscular exertion. The former includes the force expended in the digesting of food, the beating of the heart, etc.; the latter that expended in moving the body, i. e., in the motion of forward progression, and in drawing or carrying a load. The latter factor is the one of most importance in considering the horse as a beast of burden. The amount of such muscular work has been calculated or measured in various ways. The methods of calculation are often complex and need not be discussed in detail. The amount of muscular work performed has usually been measured with some form of dynamometer. An extended series of experiments in which such an instrument was employed was conducted by Wolff.[a] The dynamometer which he used consisted of a revolving arm, turning on a base, which could be weighted so as to increase the friction and hence the amount of work required to turn it. There were special devices for recording the number of revolutions made.

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[a] Quoted by Lavalard, loc. cit.

According to the classic experiments of James Watts, a horse can exert a power equal to 33,000 foot-pounds per minute, i. e., in 1 minute can exert a force sufficient to raise 33,000 pounds 1 foot. This value has been termed 1-horse power and has been accepted as a common unit for the measurement of force. In countries where the metric system is employed the more common unit is the kilogrammeter. This unit is equal to 7.2 foot-pounds. According to Watts's values, a horse working eight hours per day would perform work represented by 33,000 × 60 × 8 = 15,840,000 foot-pounds. Later estimates give lower values. It has been calculated that an average horse will produce only about 22,000 foot-pounds per minute, which would be equivalent to 10,560,000 foot-pounds in a working day of eight hours.

According to Wolff's experiments,[a] the day's work of a horse hauling a load eight hours on a level road amounted to 7,999,800 foot-pounds. Working the same length of time with a dynamometer the work amounted to 12,996,000 foot-pounds. As will be seen by the figures given below (p. 61), Lavalard obtained larger values in his calculations representing the amount of work performed daily by army horses.

Mention should be made in this connection of some comparatively recent investigations carried on at the American experiment stations and other institutions. At the Utah, New York (Cornell), Michigan, and Missouri stations and at the University of Tennessee, Sanborn, Roberts, Fulton, Waters, and Carson have studied the draft of different kinds of wagons under different road conditions and related topics, thus securing data for estimating the work done by horses under the conditions studied although the experiments were not made from this standpoint. A number of the experiment stations have also devoted considerable attention to testing the draft of plows and other agricultural implements.

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[a] For full accounts of the extended experiments of Wolff and his associates concerning the digestibility of different feeds, the production of muscular work, etc., see Landw. Vers. Stat., 20 (1876–77), p. 125; 21 (1877–78), p. 19. Landw. Jahrb., 8 (1879), Sup. I; 13 (1884), p. 257; 16 (1887), Sup. III; 24 (1895), p. 125; also Grundlagen für die rationelle Fütterung des Pferdes, Berlin, 1885.

When a horse does road work it is evident that a large animal must expend more energy than a small one for the motion of forward progression. Lavalard[a] made weighings in experiments with some 30,000 horses belonging to the Paris cab companies and to the French army. He gives the average weight of horses of different kinds and of mules as follows:

TABLE 6.—*Average weight of horses.*

	Weight.	
	Kilograms.	Pounds.
Heavy draft horses	700–800	1,540–1,760
Light draft horses	500–600	1,100–1,320
Fancy horses, reserve cavalry horses, and horses of the line	450–510	990–1,120
Carriage horses and light cavalry horses	380–400	835–880
Artillery and train horses	480–495	1,055–1,090
Mules	430	945

Taking into account the average amount of muscular work expressed in foot-pounds, the speed at which work is performed, the duration of the work, and the amount of work done at a walk and trotting, the total work done per day by army horses carrying a rider weighing 80 kilograms (175 pounds) without a pack, and 120 kilograms (265 pounds) with a pack, and 90 kilograms (200 pounds) with accouterment for maneuvers, was calculated to be as follows:

TABLE 7.—*Work performed by army horses per day.*

Work per day.	Weight carried.	Velocity per second.	Work per second.	Duration of daily work.	Amount of work at different gaits.
ORDINARY WORK (RIDER WITHOUT PACK).	*Pounds.*	*Feet.*	*Foot-lbs.*	*Hrs. Min.*	*Foot-lbs.*
Walking	176	5.446	958.5	2 30	8,626,500
Trotting	176	9.022	1,587.9	1 30	8,574,660
Total					17,201,160
ROAD WORK (RIDER WITH PACK).					
Walking	265	5.446	1,443.2	1 30	7,793,280
Trotting	265	9.022	2,390.8	1 30	12,910,320
Total					20,703,600
MILITARY MANEUVERS (RIDER WITH LIGHT PACK).					
Walking	198	5.446	1,078.3	2 00	7,762,760
Trotting	198	9.022	1,786.4	3 00	19,293,120
Total					27,055,880

According to the calculation of an English army officer, Maj. F. Smith,[b] the mean ratio of carrying power to body weight is 1 : 5.757; that is to say, it takes, roughly speaking, 5.75 pounds of body weight to carry 1 pound on the back during severe exertion (racing excepted). The rule he gives for ascertaining the carrying power of a horse is to divide his body weight by 5.757, and if intended for only moderate work to add to the product 28 pounds. It has to be noted that the observations were made upon military horses. It is doubtful if it would work out so accurately if applied to all horses used for the saddle.

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[a] Loc. cit.

[b] Queensland Agr. Jour., 4 (1899), p. 493.

According to Lavalard[a] the general opinion of cavalry officers who have studied the question is that measuring the distance covered and the rate of speed is practically the only method for determining the work done by a saddle horse. He states that Marcy computes that the work accomplished in a given time is proportional to the square of the velocity, his coefficients being 3.42 for walking or pacing, 16 for trotting, 28.62 for cantering, and 68.39 for a full gallop. In other words, 4.5 times as much work is performed when trotting as when walking, 1.75 times as much when galloping as trotting, and 2.5 times as much at a full gallop as on an ordinary trot or canter. These values are calculations rather than results obtained by experiments.

According to Poncelet[b] a horse carrying a weight of 120 kilograms (265 pounds) and traveling at a speed of 1.1 meters (3.6 feet) per second for 10 hours per day performs 4,752,000 kilogrammeters (34,214,400 foot-pounds) of work. If the weight carried equals 80 kilograms (363 pounds) and the speed is 2.2 meters (7.3 feet) per second, 4,435,000 kilogrammeters (31,932,000 foot-pounds) of work will be performed in 7 hours.

The Prussian cavalry horses, according to Ellenberger's[b] estimation, perform 1,500,000 kilogrammeters (10,800,000 foot-pounds) of useful work daily during the winter months. In the spring and summer months extra military duties increase this amount by 200,000 kilogrammeters (1,440,000 foot-pounds) daily. Different values have been proposed by other investigators for saddle horses of various kinds.

The speed at which the horse travels, the way in which the load is distributed, the external temperature, and other conditions evidently have an effect upon the work performed.

According to Colin's[b] figures a horse walking 1 kilometer (0.63 mile) in 10 minutes travels at a speed of 1.66 meters (5.4 feet) per second. Trotting the same distance in 4.25 minutes the distance covered is 3.92 meters (12.9 feet) per second. The average speed of a trotting horse was calculated to be 2.72 meters (8.9 feet) per second. These values refer especially to army horses.

MUSCULAR WORK IN ITS RELATION TO THE RATION.

Many experiments have been made, chiefly in Europe, to determine the exact relation between the amount of muscular work performed and the amount of the different nutrients required per day. It is the opinion of Wolff and Muntz, and others who have been especially active in the study of these problems, that provided a sufficient amount of protein is supplied for physiological maintenance, i. e., to replace the wear and tear of body tissue, it is immaterial which of the three classes of nutrients (protein, fat, and carbohydrates) furnishes the energy necessary for external muscular work performed by horses. The opinion of these investigators, which is quite generally accepted, has been summarized as follows by Warington:[a]

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[a] Experiment Station Record, 12 (1900–1901), p. 4.

[b] Quoted by Lavalard, loc. cit.

> The doctrine laid down by Wolff and his fellow workers at Hohenheim is a very simple one. He distinguishes between the food necessary to maintain the horse at rest without loss of weight and the extra food which must be given when work is performed, if the horse is again to be maintained, without its weight suffering loss. Between the weight of digestible matter in this extra food and the quantity of work accomplished there is a tolerably uniform relation. Wolff reckons that digested nutritive matter equivalent to 100 grams of starch is capable of producing 85,400 kilogrammeters of work, or, expressed in English terms, 1 pound of starch digested by a horse will accomplish 1,232 foot-tons of work. This is 48 per cent of the full work which the starch could accomplish if burned outside the body. The result is the average of many experiments with different diets.
>
> The horse requires for its maintenance in weight while at rest a certain daily supply of albuminoid substance [protein], which must never fall below a certain quantity; but the extra food given when work is to be performed may consist indifferently of any digestible combustible substance, whether albuminoids or not. The horse keeper is thus at liberty to select from a wide range of foods, and is not obliged to give a preference to those which are specially nitrogenous. It should, however, be borne in mind that what has just been said applies strictly only to horses which are already in good working condition. Horses which are low in condition, and must gain in weight of muscle before they are fit for hard work, must, of course, receive a more nitrogenous diet.

A view very commonly held to-day is much the same and in accord with the above, viz, that provided an adequate quantity of protein and energy are available for maintenance, it is theoretically immaterial which class of nutrients furnish the energy for muscular work, although carbohydrates and fat are practically better suited for this purpose than protein, since any great excess of the latter is costly and may prove injurious to the health. In this case the term maintenance is not used in its strict physiological sense, but refers to a condition in which no appreciable amount of external muscular work is performed, and in which the internal muscular work is fairly uniform from day to day and the body weight practically constant. Most of the experiments reported on the effect of muscular work on the amount of nutrients required have had to do with external muscular work. A number of these investigations are referred to below. The effect of internal muscular work on food requirements has also been studied, especially in recent years. The experiments of this sort are referred to on page 68.

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[a] Jour. Bath and West of England Soc., 4. ser., 4 (1893–4), p. 188.

The experiments which have had to do with the rations best suited for horses employed at different kinds of work are obviously attempts to suit the food to the amount of work performed.

Lavalard[a] calculated the amount of food required by army horses and mules to maintain weight on a peace and war footing as follows, the amount of work in the latter case being more than in the former.

Table 8.—*Calculated ration of French army horses and mules.*

	Peace footing.		War footing.	
	Oats.	Hay.	Oats.	Hay.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Cavalry horses, reserve	13	8.8	14.7	8.8
Cavalry horses, line	11.5	7.7	13.5	7.7
Light cavalry horses	10.4	6.6	11.8	6.6
Horses of artillery and train	12.3	8.5	14.2	8.5
Mules	10.8	7.5	....	....

Similar calculations, which have been made by others, have been summarized in Table 5, page 49.

Grandeau's experiments[b] have shown the marked effect of pace on the amount of labor performed and food required. He showed that a horse walking 7.8 kilometers (5.8 miles) per day neither gained nor lost in weight on a daily ration of 8,800 grams (40 pounds) of hay, while a ration of 10,886 grams (49.5 pounds) was not sufficient, provided the horse trotted the same distance. When the horse walked the above distance and drew a load, the additional work being equivalent to 60,449 kilogrammeters (437,080 foot-pounds), a ration of 11,975 grams (26.4 pounds) of hay was sufficient for maintenance. A ration of 14,787 grams (32.6 pounds), all a horse would consume, was not sufficient for maintenance when the same work was done trotting.

According to Grandeau[b] a horse of 500 kilograms (1.100 pounds) weight by the motion of forward progression through a horizontal distance of 10 kilometers (6.2 miles) at a speed of 1.5 meters (4.9 feet) per second loses 2.4 kilograms (5.3 pounds) in weight. A horse of the same weight covering a distance of 10 kilometers (6.2 miles) at a speed of 1.5 meters (4.9 feet) per second and producing 190,000 kilograms of work loses about 3.8 kilograms (8.4 pounds) in weight. Some of the reasons given for the fact that rapid work is less economical than slow work are the increased action of the heart when the horse is trotting or galloping; the lifting of his own weight at each step only to allow it to fall again, thus developing heat; and the increase of body temperature with exertion and the loss of heat by the evaporation of water through the skin and lungs. Grandeau determined the average amount of water thus evaporated under different conditions of work and rest with four different rations, the distance covered in every case being the same, and found that it varied from 6.4 pounds with a horse at rest to 20.6 pounds with a horse trotting and drawing a load. (See also p. 38.) The heat required for the evaporation of this amount of water is quite large and necessitates the combustion of a considerable amount of nutritive material in the body, thus diminishing the quantity of material available for the production of work.

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[a] Loc. cit.

[b] See note, p. 66.

EFFECT OF MUSCULAR WORK ON DIGESTIBILITY.

Grandeau's and Leclerc's experiments also indicate that the kind of work performed has some effect on digestibility. If the total amount of organic matter digested while at rest be represented by the number 1,000, the proportion digested during different kinds of work is shown, they consider, by the following table:

Relative proportion of total organic matter digested by horses at different conditions of rest and work.

At rest	1,000
Walking	1,032
At work walking	1,007
Trotting	976
At work trotting	973
Drawing a cab	959

We see here that the moderate exercise is accompanied by a small but distinct improvement in the digestive functions, but that as soon as trotting commences digestion becomes less efficient than when at rest, while hard work while trotting still further diminishes the proportion of food digested. When we look into the details we find that the starch and sugar in the food are perfectly digested under all conditions of labor. The digestibility of the fat increases with exercise and does not diminish by labor below the point reached in repose. The digestibility of the albuminoids increases rather considerably with exercise and diminishes sharply when trotting commences. The principal matters usually grouped as soluble carbohydrates, but which in this case are merely the more digestible constituents of the fiber, undergo the greatest amount of variation, their digestibility rising considerably with exercise and falling still more considerably with hard labor. In the case of the more soluble portion of the fiber there is no rise in digestibility by exercise; the maximum rate of digestion is here obtained in repose, and diminishes considerably with increased bodily exertion. On the whole it appears that the constituents of the food which are most affected by rapid exertion are those whose digestion takes place to a large extent in the lower part of the intestines; the motion of the horse probably determines their more rapid progress through the system.

From the results of earlier experiments with German farm horses, Wolff, Kellner, and associates[a] concluded that muscular work diminished digestibility little, if at all. The coefficients of digestibility of the ration when work was performed were slightly lower, but the differences were so small that they are regarded as of no importance. Grandeau's and Leclerc's values are within 3 per cent of those found by Wolff, and it seems fair to say that from a practical standpoint the diminished digestibility due to muscular work is not very important.

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[a] Landw. Jahrb., 8 (1879), sup. I., p. 73.

METABOLISM EXPERIMENTS AND THE DEDUCTIONS DRAWN FROM THEM.

There are many other complicated questions in horse feeding which have received much attention from investigators. As in experiments with man, the factors which serve as indices of changes going on in the body have been studied in this connection, the principal ones being (1) the balance of income and outgo of nitrogen, or nitrogen and carbon (as in metabolism experiments and respiration experiments), which is quickly modified by variations in food, work, and other conditions; (2) the amount of carbon dioxid produced per second as compared with the amount of oxygen consumed from the air, i. e., the respiratory quotient, which changes very quickly when any change takes place in the vital processes or in other forms of internal muscular work or when the amount of external muscular work varies. In determining the income and outgo of nitrogen the food, urine, and feces must be measured, and the amount of nitrogen in each determined. No very complicated apparatus is required, and such experiments are comparatively numerous. Where the income and outgo of carbon is determined, as well as that of nitrogen, the experiments necessitate the use of a respiration apparatus. In such experiments it is possible to calculate the balance of income and outgo of matter. If at the same time devices are used which permit the measurement of heat, the balance of income and outgo of energy may be studied also. The experiments of Boussingault, Wolff, Kellner, Hofmeister, Henneberg, and others, in which the balance of income and outgo of nitrogen were determined, have led to a number of interesting conclusions, some of which have already been referred to. Others follow.

Boussingault, who was one of the first to study these problems, showed that no nitrogen was assimilated from the air, but that all which was used in the body came from nitrogen compounds consumed in the food—a very important deduction, since it showed that no nitrogen could be taken from the air, and, that nitrogenous food was essential. The investigations of Grandeau, Leclerc, and their associates form one of the most extended studies ever undertaken with farm animals. The work was carried on with a very large number of horses belonging to one of the Paris cab companies, and extended over many years. There were seven series of experiments.[a] In the first, a mixed ration consisting of "maize cake," horse beans, maize, oats, hay, and straw was fed. The maize cake was made from starch factory and distillery waste, and contained a considerable portion of potato and barley as well as corn refuse. In the second series the ration consisted of hay; in the third series, of oats and straw; in the fourth series, of hay and straw; in the fifth series, of maize and straw; in the sixth series, of horse beans and oat straw, and in the seventh series, of maize cake and oat straw. Analyses were made of the food, urine, and feces.

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[a] Ann. Sci. Agron., 1884, II, p. 325; 1885, I, p. 326; 1886, II, p. 351; 1888, II, p. 211; 1892, I, p. 1; 1893, I, p. 1; 1896, II, p. 113.

The effect of the rations and their digestibility was studied while the horses were at rest, walking, trotting, at work while walking, and at work while trotting. The work consisted in turning the arm of a dynamometer a definite number of times. Experiments were also made in which the horses drew a vehicle. The effects of the rations under different conditions of rest and work on temperature and weight of the animals were studied. Many of Grandeau's and Leclerc's deductions have already been referred to, one of the most interesting being a demonstration of the high value of maize as a food for horses.

MEASURING THE RESPIRATORY QUOTIENT AND THE DEDUCTIONS DRAWN FROM IT.

Experiments in which the respiratory quotient was determined are perhaps less numerous than those mentioned above. A determination of the respiratory quotient necessitates the measurement and analysis of the air taken into the lungs and excreted from them. The experiments which have been made in Germany are ordinarily carried on with the aid of a mask which covers the head, or by the insertion of a silver tube in the trachea. In both cases the air is breathed in and out through tubes provided with suitable valves, so that the air enters through one tube and leaves through the other. The air is measured and the samples analyzed. The ratio of oxygen consumed to carbon dioxid expired in a unit of time is called the respiratory quotient.

Zuntz[a] and Hagemann and their associates have carried on a very extended series of investigations with horses. In most of these cases the respiratory quotient was determined. In many other cases other determinations, including the balance of income and outgo of nitrogen and carbon, were also made. Work was performed with a sort of treadmill and the amount could be measured. The deductions drawn from these experiments are of great interest, and some of the principal ones follow.

A horse weighing from 400 to 500 kilograms (880 to 1,100 pounds) excretes 26 to 40 liters (27 to 42 quarts) per minute from the lungs when no work is performed. If a horse takes exercise by walking the amount is increased to 80 to 90 liters (84 to 95 quarts) per minute. If 75 kilograms (542 foot-pounds) of work is done per second the respired air increases to 300 liters (317 quarts) per minute. If the work is still further increased the respired air amounts to 450 to 500 liters (475 to 528 quarts) per minute—in other words, 14 to 15 times what it was when no work was performed. However, in these different cases the ratio of carbon dioxid to oxygen has been found to vary very little.

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[a] Landw. Jahrb., 27 (1898), Sup. III; see also Deut. Landw. Presse, 23 (1896), pp. 561, 571, 579.

PROPORTION OF ENERGY OF FOOD EXPENDED FOR INTERNAL AND EXTERNAL MUSCULAR WORK.

A horse converts 38.3 per cent of the energy of food into mechanical work. On account of the energy required for respiration, the beating of the heart, etc., only about 34 per cent of the energy of the food is actually available for external muscular work. The best record for a steam engine is said to be an efficiency per indicated horsepower of 22.7 per cent on the basis of total heat supply. Per delivered horsepower the amount is probably 10 per cent less. The animal is therefore seen to be a much more efficient machine than the engine.

Tests were made with a horse walking on a level, walking up an incline, and hauling a load on a level, and it was found that in the last case the energy of the food was not quite so economically used as in the first case. On the basis of his experiments, Zuntz computes that a horse weighing 500 kilograms (1,100 pounds) and performing no work requires 3,201 grams (7.1 pounds) of total nutrients containing 1,382 grams (3 pounds) of crude fiber. By total nutrients is meant the sum of the protein, carbohydrates, and fat multiplied by 2.4.[a] Of this quantity of total nutrients not less than 2,100 grams (4.6 pounds) is required for the internal muscular work expended in digesting and assimilating the food, and 1,100 grams (2.4 pounds) for other purposes (largely some form of internal muscular work). Zuntz found that the amount of food required was affected by anything that disturbed the horse. In one experiment a horse confined in a stable was much disturbed by flies and consequently restless. The increased work in fighting the flies caused an increase of 10 per cent of the carbon dioxid excreted. This means that more food material was burned in the body than was the case when the horse was quiet, for the combustion of food in the body, it will be remembered, furnishes the carbon dioxid excreted in the breath.

In addition to other matters, Zuntz noted that the effect of body conformation had a marked effect on the economical production of work. He found that defects in external conformation and movements necessitate an increased amount of muscular exertion. This has an important bearing upon the market value of the horses. Too low a stall temperature also increases the amount of material required for maintenance. In many cases observed, this increase was hardly covered by 2 pounds of oats daily.

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[a] Zuntz uses this factor instead of 2.25, the factor commonly used by American investigators.

ENERGY REQUIRED TO CHEW AND DIGEST FOOD.

One of the most interesting of the lines of investigations followed by Zuntz was the determination of the energy required to chew and digest different foods. The experiments were complicated and too extended to describe here except in very general terms. As has been said, the respiratory quotient is a very delicate index of the changes which take place in the body, and it was found that the internal muscular work expended in chewing, swallowing, and digesting food could be determined by the variations in the respiratory quotient and the amount of carbon dioxid excreted when this kind of work was performed, as compared with the amount when the animal rested. Different feeding stuffs modified the respiratory quotient in different ways, and it was evident that some required more labor for digestion and assimilation than others. This is a matter of considerable importance, and it is evident that if two feeding stuffs of practically the same composition are digested with equal thoroughness but one requires for digestion and assimilation the expenditure of more internal muscular work than the other, it is really less valuable; in other words, the two may contain the same amount of digestible nutrients, but one causes the body more labor to assimilate than the other. On the basis of his average figures of composition and digestibility, 2.2 pounds of hay (1 kilogram) furnishes 0.862 pound of total nutrients, and 2.2 pounds (1 kilogram) of oats 1.353 pounds of nutrients. As regards nutritive value, hay and oats are therefore commonly said to be to each other as 400 : 600. As shown by Zuntz's experiments, 0.265 pound (115 grams), or 20 per cent of the total nutritive material present in 2.2 pounds (1 kilogram), of oats is expended in the labor of chewing and digesting them. In the case of 2.2 pounds (1 kilogram) of hay, 0.448 pound (205 grams), or 49 per cent of the total nutritive material, is required for the same purpose. Therefore hay and oats stand really in the proportion of 203 : 480. In other words, oats surpass hay in feeding value two and one-half times instead of one-half times, as they are ordinarily assumed to do.

"TRUE NUTRITIVE VALUE" OF FEEDING STUFFS.

Taking into account the internal muscular work required to chew and digest foods and deducting this from the digestible nutrients present in the foods, Zuntz calculated what we may call the "true nutritive value" of a number of feeding stuffs with special reference to horses. The results are shown in the following table:

TABLE 9.—*Calculated "true nutritive value" of 1 pound of different feeding stuffs.*

Feeding stuffs.	Dry matter.	Crude fiber.	Total digestible nutrients.[a]	Labor expended in chewing and digestion.		True nutritive value.	
				In terms of energy.	In terms of nutrients.[a]	In terms of energy.	In terms of nutrients.[a]
	Per cent.	*Pound.*	*Pound.*	*Calories.*	*Pound.*	*Calories.*	*Pound.*
Meadow hay (average quality)	85	0.260	0.391	376	0.209	328	0.182
Alfalfa hay cut at beginning of bloom	84	.266	.453	394	.219	422	.234
Red clover hay	84	.302	.407	429	.239	303	.168
Winter wheat straw	86	.420	.181	535	.297	−209	−.116
Oats (medium quality)	87	.103	.615	224	.124	883	.491
Maize	87	.017	.785	148	.082	1,265	.703
Field beans	86	.069	.720	200	.111	1,096	.609
Peas	86	.059	.687	183	.102	1,054	.586
Air-dry disembittered lupines	86	.157	.645	294	.163	867	.482
Linseed cake	88	.094	.690	225	.125	1,018	.565
Potatoes	25	.010	.226	49	.027	358	.199
Carrots	15	.016	.113	37	.021	166	.092

[a] Protein, plus carbohydrates, plus crude fiber, plus fat multiplied by 2.4.

As will be seen, the nutritive value of straw is negative in the above table. The authors call attention to the investigations which showed that so long as heat alone is considered, the digestible nutrients in straw should be given their full value as shown by the heat of combustion. Provided the labor of digesting a mixed ration does not exceed 2,100 grams (4.63 pounds, or 8,316 calories), the digestible nutrients in straw have a positive value. Provided the labor of digestion is greater than this an excess of straw would only increase the internal muscular work, so that approximately 116 grams (0.256 pound) of nutrients per kilogram is of no value for the body.

From the table the amount of any food or combination of foods required for maintenance may be calculated, according to the authors, as follows: When a horse weighing 500 kilograms (1,100 pounds) is fed hay alone, 8.2 kilograms (18.04 pounds) would be necessary, since, as previously stated, 3,200 grams (7.05 pounds) of nutrients are required for maintenance. As shown by the table, a kilogram of hay contains 391 grams (0.86 pound) total nutrients.

If the ration consists of 3 kilograms (6.6 pounds) of hay and 1 kilogram (2.2 pounds) of straw and it is desired to make up the balance with potatoes, the amount necessary may be calculated as follows:

	Grams.	Pounds.
Three kilograms (6.6 pounds) of hay furnish total nutrients amounting to	1,173	2.586
One kilogram (2.2 pounds) of straw furnishes total nutrients amounting to	181	.399
Total	1,354	2.984

Since the horse requires for maintenance 3,200 grams (7.053 pounds) nutrients, there remain 1,846 grams (4.07 pounds) total nutrients to be supplied by potatoes. This, divided by 226, the total nutrients in a kilogram (2.2 pounds) of potatoes, gives 8.2 kilograms (18.04 pounds) as the amount which must be added to the ration.

FIXING RATIONS ON THE BASIS OF INTERNAL AND EXTERNAL MUSCULAR WORK.

Zuntz believed that a ration suited to the performance of any kind of work can be calculated on the basis of the nutritive material and energy required for maintenance plus that needed for the work performed. The calculations are simplified by using the figures for "true nutritive value" given in the table above. On the basis of his experiments and observations he has calculated that a horse weighing 500 kilograms (1,100 pounds) requires for maintenance 3,201 grams (7.056 pounds) of true available nutrients. The amounts of true available nutrients and the energy required for the performance of work of different kinds and under different conditions by a horse weighing 500 kilograms (1,100 pounds), with a harness weighing 20 kilograms (44 pounds) are shown in Table 10. The value of total nutrients represents the protein + the carbohydrates + the fat × 2.4. Fat is multiplied by 2.4, since, as stated on another page (68), it yields, according to Zuntz, that much more heat per gram than protein or carbohydrates when burned in the body.

TABLE 10.—*Available nutrients and energy needed for different kinds of work.*

	Total nutrients required.		Energy required.
	Grams.	*Pounds.*	*Calories.*
Forward progression per kilometer (3,281 feet) on level at speed of 66.7 meters (218.8 feet) per minute	37.6	0.083	149
Forward progression per kilometer (3,281 feet) on level at speed of 90 meters (295.4 feet) per minute	47.7	.105	189
Forward progression per kilometer (3,281 feet) on level at speed of 176–205 meters (577.4 feet–672.6 feet) per minute	71.5	.158	283
Climbing a gentle incline, raising body 100 meters (3,281 feet)	90.0	.198	356
Climbing a steep incline, raising body 100 meters (3,281 feet)	91.7	.202	363
Descending an incline, lowering body 100 meters (3,281 feet) on road with 5 per cent dip saves[a]	37.8	.083	150
Drawing a load on level 268 (work equivalent to plowing one hour, i.e., drawing a plow weighing 67 kilograms (147.4 pounds) a distance of 4 kilometers (13,124 feet):			
Not including forward progression	508.9	1.122	2,015
Including forward progression	659.3	1.454	2,611
Raising a load weighing 75 kilograms (165 pounds) 0.2 kilometer (656.2 feet) up incline of 10 per cent:			
A. For the 0.2 kilometer (656.2 feet) of forward motion	7.52	.017	29.8
B. For raising the body and harness 20 meters (656.2 feet)	18.33	.040	72.6
C. For 1,500 kilogrammeters (10,800 foot-pounds) mechanical work.	39.15	.086	155.0
Total	65.0	.143	257.4
Trotting on level 1 kilometer (3,281 feet) with load of 75 kilograms (165 pounds):			
A. For forward motion, 1 kilometer (3,281 feet)	71.5	.158	283.0
B. For 75,000 kilogrammeters (540,000 foot-pounds) calculated mechanical work	142.4	.314	563.9
Total	213.9	.472	846.9
Progression on level 1 kilometer (3,281 feet) with 100 kilograms (220 pounds) load:			
A. At speed of 5.4 kilometers (17,717.4 feet) per hour	59.2	.131	234.5
B. At speed of 10.5–12.6 kilometers (34,451 feet–41,341 feet) trotting.	91.0	.201	360.4
Climbing 1 kilometer (3,281 feet) on an incline of 10 per cent with 100 kilograms (220 pounds) load at speed of 5.4 kilometers (17,717 feet) per hour:			
A. For forward progression	59.2	.130	234.5
B. For 60,000 kilogrammeters (432,000 foot-pounds) mechanical work (climbing)	103.8	.229	411.0
Total	163.0	.359	645.5

[a] As compared with forward progression.

As will be seen, the amount of total nutrients required increases with the increased speed; furthermore, a greater amount is required in climbing an incline than for forward progression on a level. In descending a gentle incline a much smaller amount of nutrients is required than in climbing the same incline, and as compared with the motion of forward progression there is also a saving in the amount of nutrients needed. In general, it was found that the energy expended was less than in traveling on a level, provided the incline was less than 5° 45′. At this point it was equal to the amount expended in traveling on a level. If the incline was greater, energy was required to keep the body from descending too rapidly and the expenditure was greater than on a level. The different values given in the above table for the nutrients required for the performance of different kinds of work are obtained by taking the sum of the requirements for the different components into which the work can be resolved; thus, in trotting 1 kilometer (3,281 feet) with a load of 75 kilograms (165 pounds) the total work consists in that expended for forward progression and for moving the load over the distance covered.

An example of the way in which the value of a ration was calculated by Zuntz follows:

If a farm horse weighing 500 kilograms (1,100 pounds) walks eight hours drawing a load at a speed of 4 kilometers (2.5 miles) per hour, the work performed and the total available nutrients required would be as follows:

TABLE 11.—*Total nutrients required for work.*

	Total nutrients.	
	Grams.	*Pounds.*
32 kilometers (20 miles) forward progression	1,203	2.654
2,144,000 kilogrammeters (15,436,800 foot-pounds) mechanical work	4,071	8.975
Maintenance (exclusive of labor of digestion)	1,100	2.425
Total	6,374	14.054

The ration selected consisted of 3 kilograms (6.6 pounds) hay, 1.5 kilograms (3.3 pounds) straw, 2 kilograms (4.4 pounds) field beans, and a sufficient amount of oats to bring the total nutrients of the ration up to the required amount. The nutrients furnished by the hay, straw, and field beans would be as follows:

TABLE 12.—*Total nutrients furnished by tentative ration.*

	Total nutrients.	
	Grams.	*Pounds.*
3 kilograms (6.6 pounds) of hay, requiring per kilogram (2.2 pounds) for digestion 627 grams (1.38 pounds)	+546	+1.204
1.5 kilograms (3.3 pounds of straw, requiring per kilogram (2.2 pounds) for digestion 445 grams (0.98 pound)	−174	−.384
2 kilograms (4.4 pounds) of beans, requiring per kilogram (2.2 pounds) for digestion 222 grams (4.9 pounds)	+1,218	+2.685
Total, 1,294 grams (2.85 pounds)	+1,590	+3.505

Subtracting 1,590 grams (3.505 pounds) from 6,374 grams (14.054 pounds) gives 4,784 grams (10.549 pounds), the total available nutrients which must be supplied by the oats. Dividing this sum by 491, the total available nutrients in a kilogram (2.2 pounds) of oats, gives 9.74 kilograms (21.43 pounds) as the amount required. This quantity of oats would require the expenditure of 1,208 grams (2.660 pounds) nutrients for the labor of digestion (9.74 kilograms×0.124=1.208 kilograms) (2.660 pounds). The total expenditure of nutrients which the ration necessitates for the labor of digestion would therefore be 2,502 grams (5.514 pounds) (1,294 grams+1,208 grams=2,502 grams) (2.854 pounds+2.660 pounds=5.514 pounds). This exceeds by some 400 grams (0.882 pound), the value which is thought most desirable for the normal maintenance ration, i. e., 2,100 grams (4.630 pounds). The expenditure of this amount of nutrients for the work of digestion is thought desirable, because it would liberate the amount of heat which Zuntz calculates is required for maintaining the body temperature.

The ration may be adjusted on a more reasonable basis by diminishing the straw to 0.3 kilogram (0.66 pound) and the oats to 9.46 kilograms (20.812 pounds). The total quantity would be the same as before, and the amount required for the labor of digestion would be practically equal to that which is considered most desirable. The ration as adjusted would be as follows:

TABLE 13.—*Calculated ration for farm horse at work.*

Ration.	Requires for the labor of digestion.		Yields total nutrient.	
	Grams.	Pounds.	Grams.	Pounds.
3 kilograms (6.6 pounds) hay	627	1.382	546	1.204
2 kilograms (4.4 pounds) beans	222	.489	1,218	2.685
0.3 kilogram (0.66 pound) straw	89	.196	−35	.077
9.46 kilograms (20.812 pounds) oats	1,173	2.586	4,645	10.241
Total	2,111	4.653	6,374	14.207

This ration is, according to Zuntz, more satisfactory on economic grounds, since it does not contain an excess of material which must be wastefully assimilated. The fact is also pointed out that it might not prove satisfactory otherwise, since it contains a small amount of coarse fodder. The other examples given by Zuntz are more complicated.

SUMMARY.

Some of the principal deductions noted in this bulletin follow:

Horses, like other animals, require a definite amount of nutrients and energy per 1,000 pounds live weight for maintenance, and an extra amount, chiefly energy-yielding nutrients, for muscular work, the amount being proportional to the character and amount of work performed.

The amount of nutrients required increases with the amount of work done and with increased speed. More energy is required for climbing an incline than for traveling on a level. In descending an incline of less than 5° 45′ less energy is required than in traveling on a level. If the incline is greater than 5° 45′, more energy is expended (to prevent too rapid descent) than in walking on a level.

The ration should consist of concentrated and coarse feeds. The ratio by weight of coarse fodder or bulky feed to concentrated feed in the ordinary ration has been found to be about 1:1. Crude fiber may perhaps be fairly considered as the characteristic constituent of coarse fodder. The ratio of crude fiber to protein in the average of a large number of American rations has been found to be about 2:1.

Theoretically at least any sufficient and rational mixture of wholesome grains, by-products, roots, and forage crops, green and cured, may be used to make up a ration, though there is a very general prejudice in favor of oats and hay, corn and hay or corn fodder, and barley and hay (frequently that made from cereal grains), the first-named ration being perhaps that most commonly regarded as satisfactory for horses. A corn ration is very commonly fed in the middle West and Southern United States—that is, in the corn-producing belt. The barley ration is quite characteristic of the Pacific coast region. In the semiarid regions of the United States Kafir corn and alfalfa have proved to be of great value, owing to their drought-resisting qualities. Both crops have been found useful for horse feeding. Of the two alfalfa has been used much more commonly, and has given very satisfactory results.

Investigations have shown that it is often best to modify a ration, for instance, by substituting corn wholly or in part for oats, so that the horses remain in good condition, while at the same time the cost of the ration is diminished. Where large numbers of horses are fed this is often a matter of considerable importance.

Horses require a considerable amount of water daily, the quantity varying with different seasons of the year, the amount of work performed, etc. The time of watering, whether before or after feeding, is a matter of little importance, and, generally speaking, may be regulated to suit the convenience of the feeder. Horses become used to either method of watering, and irregularity should be avoided, as sudden changes are apt to prove disturbing.

Judging by the average results, representing the practice of a large number of successful American feeders, and also the results of many tests at the experiment stations in different parts of the United States, horses with light work consume on an average a ration furnishing per day 0.99 pound of digestible protein and 14,890 calories of energy per 1,000 pounds live weight. Similar values for horses at moderate work are 1.49 pounds digestible protein and 22,710 calories, and for horses at severe work 1.12 pounds digestible protein and 19.560 calories. It is believed that these last values do not come as near representing a general average as the others, since they are based on a comparatively limited amount of data, and possibly the pace at which the work was performed may be responsible in a measure for the comparatively small amounts of nutrients and energy. Generally speaking, all these average values are less than those called for by the commonly accepted German feeding standards for horses performing the same amounts of work, yet from what is known regarding the American horses it seems fair to say that they were well fed.

Additional experiments are much needed which will result in a series of standards suited to American conditions.

Generally speaking, horses digest their feed, and especially the nitrogen-free extract and crude fiber in it, less thoroughly than ruminants.

The general deductions which have been drawn for horses apply with equal force to other animals of the same group, such as asses and mules.

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A. C. TRUE, Director.

STUDIES ON THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD

AT

THE UNIVERSITY OF MINNESOTA

IN

1900–1902.

BY

HARRY SNYDER, B. S.,

Professor of Chemistry, College of Agriculture, University of Minnesota, and
Chemist, Agricultural Experiment Station.

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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 126.

A. C. TRUE, Director.

STUDIES ON THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD

AT

THE UNIVERSITY OF MINNESOTA

IN

1900–1902.

NEW YORK
BOTANICAL
GARDEN

BY

HARRY SNYDER, B. S.,

*Professor of Chemistry, College of Agriculture, University of Minnesota, and
Chemist, Agricultural Experiment Station.*

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., February 15, 1903.

Sir: I have the honor to transmit herewith, and to recommend for publication as a bulletin of this Office, a report of investigations on the digestibility and nutritive value of bread carried on at the University of Minnesota in 1900–1902 by Harry Snyder, professor of chemistry in the State university and chemist of the agricultural experiment station. The studies were conducted under the immediate supervision of Prof. W. O. Atwater, chief of nutrition investigations, and Prof. Charles D. Woods, and form a part of the investigations on food of man conducted under the auspices of this Office. Thanks are due the Northwestern Consolidated Milling Company, of Minneapolis, Minn., for specially grinding samples of hard wheat, and to the Goshen Milling Company, of Goshen, Ind., and the Christian Breisch Milling Company, of North Lansing, Mich., for similar favors with respect to soft wheat.

The results of these investigations are in accord with those obtained in former studies, and indicate that fine patent flours from both hard and soft wheat are more digestible than corresponding coarse flours, though they contain somewhat less protein and mineral matter pound for pound. The investigations also show that all flours are quite thoroughly digested, and furnish experimental proof of the generally recognized fact that wheat flours of all grades are among the most important articles of diet.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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STUDIES ON THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD.

INTRODUCTION.

The investigations reported in this bulletin, which were carried on at the University of Minnesota in 1900–1902, are a continuation of the experiments on the digestibility and comparative nutritive value of bread made from different grades of flour reported in previous bulletins of this Office,[a] and include two series of digestion and nitrogen metabolism experiments with healthy men on a diet of milk and bread made from different grades of wheat flour, namely, straight patent, entire wheat, and graham. In the first series, which included 9 experiments carried on in 1900–1901 (pp. 20–31), the different grades of flour used were all ground from the same lot of hard Scotch Fife spring wheat. In the second series, which included 15 experiments, carried on in 1901–2 (pp. 32–50), the flours were ground from soft winter wheat.

The standard grades of flour produced by the modern process of milling are discussed in detail in a former bulletin[b] and also in later pages of this bulletin. Briefly stated, by graham flour is meant the product obtained by grinding the entire wheat kernel. Entire-wheat flour is the product obtained by removing about one-half of the coarse bran before grinding. This flour is finer than graham, but not as fine as the patent grades of flour. In milling the patent flour all of the bran is removed. Several grades of patent flour are produced, but the one most commonly found on the market, known as "standard patent," "straight patent," or "straight grade" consists of the first and second patent and first clear grades combined. By ordinary processes of milling a little over 72 per cent of the total wheat is recovered as straight or standard patent flour and about 2.5 per cent as low grade and "red dog" flours, the remaining 25 per cent being returned in the form of bran, shorts, and other offal.

During late years the relative food value and merits of these different kinds of flour have been the subject of extensive discussion; but an examination of the literature on bread and flour shows that but few digestion experiments which are really directly comparable have been made with the different kinds of flour. Wheat ranges in protein content from about 11 to 17 per cent; therefore, in order that the results of experiments may be comparable, the three kinds of flour should be milled from the same lot of wheat. In the former report it was shown that when the three different kinds of flour were ground from the same lot of hard spring wheat the graham and entire-wheat flours contained a little more protein and gave a slightly higher fuel value than the straight patent flour; but the coarser graham and entire-wheat flours had a lower coefficient of digestibility than the finer straight patent flour. Hence the straight patent flour furnished the body more nutritive material per gram or per pound than either the graham or entire-wheat flour. Because of the importance of the subject and the extensive use of wheat as a human food it was deemed desirable to repeat the work, and in so doing to extend the periods of the digestion experiments over a longer time than in the case of the experiments previously reported, in which they were only two days each. The experiments of 1900–1901 were therefore practically a repetition of those of 1899–1900, except that the digestion period in each case was twice as long, i. e., four days.

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[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 67 and 101.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, pp. 7, 8.

In 1901–2 experiments were made similar to those of 1900–1901, but with soft winter wheat, which is somewhat different in character from the hard spring wheat, in order to determine whether the results would be the same with flours ground from different sorts of wheat.

In connection with both series of experiments a number of analyses were made of the varieties of wheat studied and of their milling products as well as of the milk which formed a part of the diet in the digestion experiments. The necessary analyses were also made of the feces and urine to secure data for use in computing the digestibility of the food and the balance of income and outgo of nitrogen.

METHODS OF SAMPLING AND ANALYSIS.

The analytical methods employed in these investigations were practically those recommended by the Association of Official Agricultural Chemists,[a] a few modifications suggested by experience being introduced.

A sample of each loaf of bread used during the separate digestion experiments was analyzed. One hundred grams of bread was reserved for the dry matter determination, and proportional parts of the dry matter of the bread from various loaves were united to form a composite sample, which contained a part of each loaf of bread proportioned to the size and moisture content of the loaf.

A composite sample was made of the milk in the experiments of 1900–1901 by saving, in a bottle containing 100 milligrams of potassium bichromate, 25 cubic centimeters of the milk used at each meal. In the experiments of 1901–2 the amount of milk reserved at each meal was 50 cubic centimeters. The temperature of the drying oven was kept at about 60° C. in all cases of the determination of moisture in the feces. The bread was also dried at this temperature. Nitrogen was determined by the ordinary Kjeldahl process. In the case of wheat and its milling products and bread, protein was obtained by multiplying nitrogen by the factor 5.7. In the case of protein in the milk and the feces the factor used was 6.25. No attempt was made to separate and determine the amount of metabolic nitrogen of the feces. Carefully purified ether was used for determining ether extract in the bread and feces. The results obtained for the fat in the feces were not satisfactory in many cases, although the determinations were made in duplicate by the method generally followed and considered reliable. The fat in the milk was determined by the Adams gravimetric method. The ash was determined by combustion at a low temperature. The carbohydrates were estimated by subtracting the sum of the protein, ether extract, water, and ash from 100.

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[a] U. S. Dept. Agr., Division of Chemistry Bul. 46, revised.

The determination of the ether extract in the feces necessarily involves an error, owing to the metabolic products present. Another source of error is in the protein determination. While the determination of the total nitrogen is satisfactory, the factor for converting this nitrogen into protein is not perfectly reliable, and in many cases is very unsatisfactory. It is well known that not all of the nitrogen of a food is in the form of proteid compounds. In the case of the food materials used in these experiments, namely, bread and milk, over 97 per cent of the total nitrogen is in the form of proteids, and the error from nonproteid nitrogen in the food is therefore small. In the case of the feces, however, the kinds, proportions, and composition of the nitrogenous ingredients are not well understood, and the estimate of "protein" is at best very crude. The errors involved in the determination of carbohydrates, by difference, are too well known to require discussion. Notwithstanding these imperfections of analytical methods, which are not peculiar to these investigations but are common to all similar experiments, the results obtained in determining moisture, ash, total nitrogen, and heat of combustion are believed to be reasonably accurate, and the deductions drawn from them are regarded as reliable.

The calorific value or heat of combustion of the various samples of food, feces, and urine was determined in the usual way by means of the bomb calorimeter. In the case of the milk and urine, weighed blocks of cellulose were employed to absorb the liquid. The absorption block was saturated, carefully dried, weighed, and again saturated with a weighed quantity of material. After drying at a temperature of 65° C. the block was burned in the calorimeter in the usual way, a correction being made in the results for the heat of combustion of the block employed.

DESCRIPTION OF SAMPLES OF FOOD MATERIALS.

In the milling of the hard spring wheat great care was taken to secure representative samples. As in the former work, the milling was carried on under the supervision of Mr. C. E. Foster, of Minneapolis, in one of the large flouring mills of that city. Two hundred pounds each of the three different kinds of flour were obtained from the mill. As soon as the samples were received at the laboratory smaller samples were drawn for analysis.

For the experiments with soft winter wheat difficulty was experienced in securing samples of soft-wheat flours that were comparable with the grades of flour used in former work with hard spring wheat. The samples of hard wheat used in 1899–1901 were exhaustively milled and very little flour was left in the bran and middlings.

The samples of soft wheat used in 1901–2 were, as is the custom with such wheats, less exhaustively milled and more flour was left in the offals. For this work sets of samples were obtained from two different milling companies, and in each case the different grades of flour were from a single lot of wheat.

A description of the different sorts of wheat used in the experiments, and of the different grades of flour and milling products made from them, is here given. These are the samples the analyses of which are reported in Table 1.

In addition to the various milling products mentioned, which are standard grades, other grades may be obtained by subdividing a grade or by mixing or blending two or more grades. Many of the flours which are placed upon the market are mixtures of two or more standard grades of flour.

No. 153. Hard Scotch Fife spring wheat, weighing 60 pounds per bushel; screened but not scoured. This wheat is representative of the hard spring wheat grown in the Northwestern wheat regions of the United States.

No. 154. Entire-wheat flour from hard spring wheat No. 153. This is the product obtained by removing a portion of the bran and grinding the remainder of the grain. It includes the germ and other parts of the offal products which are excluded from the patent grades of flour. This flour is coarser in texture and darker in color than the patent and clear grades. The presence of fine bran particles prevents perfect granulation. Such "entire-wheat" flour is sometimes called "pulverized graham" or "natural flour."

No. 155. Graham flour from hard spring wheat No. 153. This consists of the entire wheat kernel including bran, germ, and offal, ground into meal. Graham flour is practically wheat meal; no sieves or bolting cloths are employed in its manufacture, and coarse particles of bran, etc., may be observed in the flour.

No. 156. Straight patent flour from hard spring wheat No. 153. This includes the first and second patent grades and the first clear or bakers' grade of flour described below. Ordinarily about 72 per cent of the screened wheat is recovered as straight patent flour.

No. 157. First patent flour from hard spring wheat No. 153. This is the highest grade of patent flour manufactured. Ordinarily about 56 per cent of the screened wheat is recovered as first patent flour, provided no straight flour is made. All of the patent grades of flour include the middlings which, by the former processes of milling, were not reduced to flour but were included in the offal products. The presence of the granular middlings gives a relatively high protein content to the patent grades of flour.

No. 158. Second patent flour from hard spring wheat No. 153. This is similar to first patent, but the bread made from it is a little darker in color and the gluten does not possess quite so high a power of expansion. The division of the flour into first, second, and straight patent grades is based entirely upon mechanical processes. In the higher grades of patent flour the gluten is distinctly different from that in the lower grades. The higher the grade of flour, the greater the power of expansion. It is this quality which enables the flour to absorb a large amount of water and as a result produce a large-sized loaf, and one of good physical properties.

No. 159. First clear flour from hard spring wheat No. 153. After the first and second grades of patent flour are removed in milling about 12 per cent of first clear grade is obtained. This grade has a high protein content, but the gluten is different in character from that of the first and second patent grades of flour. As already explained, when the first and second patent grades and the first clear grade are blended as one product, the blend is called straight or standard patent flour.

No. 160. Second clear or low-grade flour from hard spring wheat No. 153. After the removal of the first and second patent flours and the first clear flour about 5 per cent of the original wheat can be obtained as second clear or low-grade flour. This flour is much darker in color than the patent and first clear flours. It contains gluten, with a low power of expansion, and therefore is not so valuable for bread making as the higher grades of flour. Second clear flour is characterized by a high protein content, but for bread making this protein possesses poor physical properties.

No. 161. Red-dog flour from hard spring wheat. This is the lowest grade of flour manufactured. It is sometimes used for feeding animals, and occasionally for human food. It is obtained largely from the parts adjacent to the germ or embryo, and is characterized by a high protein content, this protein, however, having different properties from that in the higher grades of flour. It possesses but little power of expansion, and the bread made from this grade of flour is dark in color and poor in quality, at least as regards its physical properties. In the process of milling the wheat germ is not included in the higher grades of flour, because its protein is not composed of gliadin and glutenin. Furthermore, the germ ferments readily, and thus when present in flour has a tendency to render it unsound. Ordinarily from 5 to 8 per cent of the screened wheat is excluded as germ. This is utilized for the preparation of breakfast foods, for blending with other cereal food products, and for other purposes. Frequently, however, the wheat germ finds its way into the shorts and is used for cattle feed.

No. 162. Wheat shorts or middlings from hard spring wheat No. 153. About 11.5 to 12 per cent of the cleaned wheat is recovered as shorts, which consist of the fine bran that has been more or less completely pulverized. When the wheat germ is recovered with the shorts, the product is known as middlings. Such "middlings" must not be confused with the middlings obtained when wheat is milled by the old process. As previously stated, the material termed middlings in the old process is now reduced and recovered in the various grades of patent flour.

No. 163. Bran from hard spring wheat No. 153. This consists of the coarsely ground episperm or outer covering of the wheat kernel. Ordinarily from 13 to 15 per cent of the cleaned wheat is recovered as bran.

No. 164. Entire-wheat bread. This was made of the flour from which sample No. 154 was taken.

No. 182. Graham bread. This was made of the flour from which sample No. 155 was taken.

Nos. 199 and 217. Straight patent flour bread. In making this bread flour was used from which sample No. 156 was taken.

Nos. 165, 181, 198, and 216. Milk. Mixed milk, used in the digestion experiments.

No. 218. Cleaned soft winter wheat, from Goshen, Ind., prepared for milling, of good quality, and weighing 60 pounds per bushel. The sample analyzed was ground in the laboratory in a Maercker mill.

No. 221. Mixed-grade flour, ground from soft winter wheat No. 218, and consisting largely of straight flour with some lower grades and a little germ. As already explained, with exhaustive milling about 72 per cent of the screened wheat is recovered as straight flour, the grade most extensively used for bread making. If a lower percentage of wheat is recovered as flour, the sample is ranked, commercially, as a higher grade of patent flour because of its lighter color and other characteristic physical properties. This sample, No. 221, was not strictly a straight grade flour, but was more properly a blend.

No. 222. Entire-wheat flour, ground from soft winter wheat No. 218, after removing a small amount of bran. This sample was different from the entire wheat used in former work with hard wheat; it had more of the characteristics of graham. It was, however, more finely pulverized than the graham flours used in the experiments made in 1899–1901.

No. 267. Middlings obtained in the milling of the straight-grade flour No. 221, from soft winter wheat No. 218. Middlings include the fine particles of bran and germ, and, in case the wheat is not exhaustively milled, a small amount of the lowest grades of flour.

No. 268. Bran, from soft winter wheat No. 218.

No. 237. Soft winter wheat, of good quality, from North Lansing, Mich., weighing 59 pounds per bushel, cleaned and prepared for milling.

No. 240. Straight grade or standard patent flour, milled from soft wheat No. 237. From the analysis of the flour and the appearance of the offals, it would seem that this flour contained somewhat less than 72 per cent of the original wheat. It should be classed as a high grade rather than as a straight-grade flour. It possessed good bread-making qualities, but required more thorough mixing and kneading than hard-wheat flours.

No. 238. Middlings, from soft winter wheat No. 237, obtained in milling flour No. 240.

No. 239. Bran, from soft winter wheat No. 237, obtained in milling flour No. 240.

No. 241. Entire-wheat flour, prepared from soft winter wheat No. 237.

No. 242. Graham flour, obtained from soft winter wheat No. 237.

No. 223. Mixed-grade flour bread. This was made of the flour from which sample No. 221 was taken.

No. 231. Entire-wheat flour bread. This was made of the flour from which sample No. 219 was taken.

No. 244. Straight patent flour bread. In making this bread flour was used from which sample No. 240 was taken.

No. 251. Entire-wheat flour bread. This bread was made of the flour from which sample No. 241 was taken.

No. 260. Graham-flour bread. The graham flour used was the lot from which sample No. 242 was taken.

COMPOSITION OF SAMPLES OF FOOD MATERIALS.

In Table 1, which follows, are given the results of the analyses of the wheat samples, of the flours and other products made from the wheat, of the bread made from the flours, and of the milk consumed in the digestion experiments.

TABLE 1.—*Composition of wheats, flours, and offals, and of bread, and milk used in digestion experiments with hard and soft wheat breads.*

Sample No.	Whence obtained.	Water.	Protein.[a]	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram, determined.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
	Hard wheat:						
153	Wheat	10.41	15.50	2.28	69.88	1.93	4.023
154	Entire-wheat flour	13.51	13.72	1.69	70.10	.98	3.877
155	Graham flour	13.21	14.21	2.01	68.56	2.01	3.971
156	Straight patent flour	12.38	13.60	1.30	72.04	.68	3.861
157	First patent flour	12.16	13.31	1.21	72.93	.39	3.960
158	Second patent flour	12.09	13.05	1.37	73.03	.46	3.904
159	First clear flour	11.92	17.73	1.98	67.37	1.00	4.072
160	Second clear flour	10.40	20.00	3.17	64.24	2.19	4.112
161	Red dog flour	10.26	21.83	6.10	57.72	4.09	4.430
162	Middlings	10.17	18.64	6.04	59.72	5.43	4.314
163	Bran	11.47	17.10	4.23	59.89	7.31	4.187
	Bread made from—						
164	Entire-wheat flour	40.97	9.32	.19	48.75	.77	2.535
182	Graham flour	42.68	9.54	.29	46.10	1.39	2.495
199	Straight patent flour	38.77	9.63	.04	51.06	.50	2.594
217	Do	37.37	9.74	.26	52.12	.51	2.647
	Soft wheat:						
218	Wheat from Indiana	8.09	13.16	1.52	75.38	1.85	4.090
219	Entire-wheat flour	9.60	12.80	1.54	74.40	1.66	4.020
221	Mixed grade flour	10.30	12.30	.93	75.94	.53	4.010
237	Wheat from Michigan	10.25	12.34	1.35	74.23	1.83	4.000
238	Middlings	7.86	17.91	5.18	65.09	3.96	4.256
239	Bran	8.74	14.96	4.41	65.78	6.11	4.108
240	Straight patent flour	10.97	10.92	.50	77.15	.46	3.799
241	Entire-wheat flour	11.01	12.01	1.53	74.17	1.28	3.860
242	Graham flour	11.23	12.24	1.41	73.27	1.85	3.906
267	Middlings	9.76	18.34	4.65	64.05	3.20	....
268	Bran	10.94	16.72	4.42	61.20	6.72	....
	Bread made from—						
223	Mixed grade flour	39.56	8.01	.60	51.32	.51	2.710
231	Entire-wheat flour	39.50	8.53	1.02	49.49	1.46	2.640
244	Straight patent flour	36.87	7.59	.38	54.67	.49	2.610
251	Entire-wheat flour	37.62	8.33	1.08	51.70	1.27	2.690
260	Graham flour	38.12	8.36	.87	51.20	1.45	2.620
165	Milk, composite sample	87.81	3.25	3.80	4.34	.80	.700
181	.....do	87.27	3.13	4.00	4.71	.89	.746
198	.....do	87.59	3.04	3.82	4.81	.74	.729
216	.....do	87.14	3.38	4.15	4.57	.76	.744
224	.....do	87.00	3.31	4.38	4.52	.79	.780
232	.....do	86.56	3.32	4.67	4.68	.77	.813
243	.....do	87.34	2.99	4.09	4.81	.77	.742
258	.....do	87.67	3.00	3.85	4.75	.73	.735
259	.....do	86.50	3.25	4.45	5.03	.77	.777

[a] In all samples except milk, protein is N×5.70; in milk it is N×6.25.

The hard Scotch Fife spring wheat selected for the experiments (sample No. 153) was characterized by a very high protein content, namely, 15.5 per cent. In an earlier publication of this Department showing the average composition of a large number of American feeding stuffs[a] the protein content of wheat is given as 11.9 per cent. The highest percentage of protein there recorded is 17.2 per cent and the lowest 8.1 per cent. It will be observed that the wheat from which these flour samples were obtained contained nearly this maximum amount of proteid material. In the investigations with hard wheat previously reported,[b] the wheat employed contained 12.65 per cent protein. The average amount of protein in the same variety of wheat is found to vary materially from year to year, depending among other things upon the amount of rainfall and the climatic conditions under which the wheat has matured. The wheat crop produced in the northwestern United States in 1900 was unusually rich in protein. The rainfall and climatic conditions seemed to be particularly favorable for producing wheat and other grains with a high nitrogen content. While the wheat employed in this investigation contained somewhat more protein than is found in average wheat, in the author's opinion the percentage is no greater than in average wheat grown in the northwestern United States in 1900. All of the flour samples from this wheat were relatively richer in protein than those in similar investigations with hard wheat in 1898–99, owing to the high nitrogen content of the wheat. The differences in the protein content of the several grades of flour ground from the wheat were comparatively small.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. No. 11, p. 17.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. No. 101.

There was a higher percentage of fat in the middlings than in the bran, owing to the presence of the germ in the former. Red-dog flour is the richest, as regards both fat and protein, of the products ground from the wheat. In the case of the patent and clear grades of flour, the heat of combustion as determined was found to agree closely with the heat of combustion obtained by calculation, using the usual factors, namely, 9.3 calories per gram[a] for fat, 5.9 for protein, and 4.2 for carbohydrates. As pointed out in a previous report,[b] the percentage of ash in the various products of wheat was lowest in the first patent flour and highest in the red-dog flour. Each grade of flour, beginning with the first patent, was found to contain proportionally more ash than the preceding grade. In fact, as noted previously, the grade of flour can be determined from the amount of ash present. In the analyses reported above the ash content is greater than in the samples employed in the earlier work with hard wheat in this laboratory. There appears to be a close relationship between the amounts of ash and protein present in flour and other milled products of wheat, any material increase in protein being accompanied by a corresponding increase in mineral matter. This has often been attributed to the phosphorus associated with the proteids. Late work of Osborne[c] indicates that the total amount of phosphorus in wheat proteids is too small to account for the increase in mineral matter just alluded to.

The distribution of the nitrogen and ash constituents of the wheat berry has been frequently studied, and it is interesting to note some comparatively recent American work on the subject, particularly as the investigations were made with wheats grown in the United States, which are therefore directly comparable with the wheats used in the investigation reported in this bulletin.

Mrs. Ellen H. Richards and Miss Lottie A. Bragg[d] studied the distribution of nitrogen and phosphorus in winter and spring wheat and their milling products, in both cases the milling products having been ground from the same lots of wheat. The results obtained are shown in the following table, which includes also values for protein obtained by multiplying the figures for nitrogen by 6.25:

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 12.

[b] Ib., p. 9.

[c] Connecticut State Station Rpt. 1900, p. 464.

[d] Tech. Quart., 3 (1890), p. 246.

TABLE 2.—*Nitrogen and phosphorus in wheat and its milling products.*

Milling products.	Water.	Phosphorus.	Nitrogen.	Protein (N×6.25).
St. Louis winter wheat:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Whole wheat	12.85	0.262	1.87	11.7
Royal patent flour	13.37	.051	1.39	8.7
Extra fancy flour	12.51	.100	1.78	11.1
Low-grade flour	11.94	.100	2.08	13.0
Middlings	11.21	.225	2.73	17.1
Bran	12.15	.828	2.62	16.4
Minnesota spring wheat:				
Whole wheat	11.09	.230	2.24	14.0
Patent flour	12.29	.050	2.10	13.1
Bakers' flour	12.14	.091	2.40	15.0
Shorts	11.27	.560	2.78	17.4
Bran	11.23	.830	2.55	15.9

The figures in the table indicate that, while a larger part of the protein is recovered in the flour than is the case with the phosphorus, there is, nevertheless, a parallelism in the proportion of protein and phosphorus in the different milling products.

At the Arkansas Experiment Station, Teller[a] made a very thorough and detailed study of the ash constituents of a sample of locally grown medium hard winter wheat and its milling products. In milling 3,000 pounds of uncleaned wheat, 1.83 per cent was recovered as screenings and 0.33 per cent as tailings, the percentage of milling products being as follows: Patent flour 25.80, straight flour 42, low-grade flour 3.87, dust room contents 1.17, ship stuff 1.13, and bran 23.80. The loss of material in grinding—that is, the material unaccounted for—was therefore only 0.07 per cent.

The principal ash constituents and the sulphur and nitrogen in the whole wheat and the different milling products were as follows:

TABLE 3.—*Ash constituents and nitrogen of winter wheat and its milling products.*

Milling products.	Total ash.[b]	In total ash.						Sulphur.	Nitrogen.
		Silica.	Ferric oxid.	Potash.	Lime.	Magnesia.	Phosphoric acid.		
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Wheat	1.62	1.04	0.27	29.70	3.10	13.23	52.14	0.13	1.96
Patent flour	.31	2.33	.47	38.50	5.59	4.39	48.05	.09	1.54
Straight flour	.40	1.28	.26	36.31	5.65	6.41	49.32	.10	1.75
Low-grade flour	.70	.50	.25	32.27	4.51	9.33	53.10	.16	2.13
Dust room material	2.50	1.34	.30	30.85	3.53	12.90	49.94	.15	2.17
Ship stuff	3.08	.49	.37	28.03	2.80	13.27	54.62	.17	2.78
Bran	5.25	.97	.27	28.19	2.50	14.76	52.81	.21	2.73

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[a] Arkansas Station Bul. 42, pts. 1, 2.

[b] This sum includes values which are given for alumina, chlorin, zinc, and sulphur trioxid, which are not quoted in the table. The author regards the values for sulphur present in the different materials as more reliable than those for sulphur trioxid in the ash, owing to a probable volatilization of sulphur in burning to obtain the ash. The other constituents omitted are not of much importance, the alumina and zinc being accidentally present.

Teller points out that about 87.5 per cent of the entire phosphoric acid, 78.5 per cent of the potash, and 37.5 per cent of the nitrogen present in the wheat berry are recovered in the milling products ordinarily used as cattle feeds. As will be seen from the above table, the percentage of phosphoric acid increases as the grade of flour decreases, being least in the patent flour and greatest in low-grade flour, the proportion present in the latter being greater than in any of the milling products except ship stuff; in other words, as shown by these figures, the phosphoric acid content, generally speaking, increases in passing from the center of the wheat berry to the outer layer, the inner portion yielding the fine flour and the outer portion the bran. The table also shows that in the various milling products the proportion of nitrogen (and hence that of protein, since the latter is computed by multiplying nitrogen by a constant factor) varies in practically the same way as the phosphorus.

The parallelism between protein and phosphorus, which was spoken of above, is borne out by the analytical data quoted, though it does not necessarily follow that the phosphorus present occurs in the true proteids.

As a whole, it has been the aim in the experiments conducted at the University of Minnesota to include standard types and varieties of hard and soft wheat flours, milled under different conditions. The differences in the percentages of flour recovered from the wheat used necessarily make slight differences in the composition and characteristics of the grades of flour obtained. The soft wheat products were of different character from the samples of similar products from hard wheat. The hard wheats had been exhaustively milled, as is the usual custom, in one of the large mills of Minneapolis, while the soft winter wheats were ground by mills of smaller capacity using somewhat different milling systems, and, as is the general commercial practice, were less exhaustively milled.

In general, the flours from soft wheat were somewhat similar to, though not in every respect like those from, hard wheat, because of the differences in the kinds of wheat used and percentages of flour recovered. The graham flour contained the largest percentage of protein, fat, and ash, while the patent grades of flour contained the smallest amounts of these ingredients. A noticeable difference in the mechanical composition of the three grades of soft wheat flour was observed. With the process of milling followed, some granular middlings were left in the offals which would have been recovered in the straight and other grades of flour with more exhaustive milling. This results in a straight-grade flour containing slightly less protein than the product of exhaustive milling, as the granular middlings are rich in this nutrient. The particles or granules of the graham flour were much larger than those of either the entire-wheat or the straight-grade flour. The comparative sizes of granules from graham, entire-wheat, and straight-grade flours ground from soft wheat are shown in the micro-photographs reproduced in Plate I, figs. 1 and 2, and Plate II, fig. 1, p. 48.

COMPOSITION OF FECES AND URINE OBTAINED IN DIGESTION EXPERIMENTS.

The composition of the dry matter of the feces from the digestion experiments is given in Table 4, while Table 5 records the amount, specific gravity, and percentage of nitrogen of the urine.

A description of the samples of feces and urine follows:

Nos. 178, 199, 180, 195, 196, 197, 213, 214, and 215 represent the feces which were obtained in the digestion experiments with hard spring wheat products.

Nos. 225, 226, 227, 233, 234, 235, 245, 246, 247, 252, 253, 254, 261, 262, and 263, the feces which were obtained in the digestion experiments of 1901–2 with soft winter wheat.

Nos. 166–177, 183–194, and 200–212, the urine from the digestion experiments with hard spring wheat products.

Nos. 228, 229, 230, 236, 237, 238, 248, 249, 250, 255, 256, 257, 264, 265, and 266, the urine obtained in the experiments with soft winter wheat.

TABLE 4.—*Composition of dry matter of feces from digestion experiments with hard and soft wheat breads.*

Sample No.	Whence obtained.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram determined.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
	Experiments with hard wheat:					
178	Experiment No. 242	30.25	12.26	34.42	23.07	4.638
179	Experiment No. 243	28.37	7.45	35.37	28.81	4.070
180	Experiment No. 244	25.00	7.44	41.35	26.21	4.351
195	Experiment No. 245	23.25	8.70	50.16	17.89	4.415
196	Experiment No. 246	23.31	5.61	47.59	23.49	3.960
197	Experiment No. 247	21.67	6.41	50.48	21.44	4.170
213	Experiment No. 248	29.94	17.46	25.02	27.58	4.720
214	Experiment No. 249	28.56	11.41	26.42	33.58	4.265
215	Experiment No. 250	23.94	9.30	36.47	30.29	4.654
	Experiments with soft wheat:					
225	Experiment No. 309	14.10	17.04	45.15	23.71	5.030
226	Experiment No. 310	21.83	15.84	38.92	23.41	5.300
227	Experiment No. 311	26.75	9.10	39.40	24.75	4.400
233	Experiment No. 312	14.31	5.36	60.48	19.85	4.340
234	Experiment No. 313	16.76	10.32	55.98	16.94	4.420
235	Experiment No. 314	20.06	4.32	56.51	19.11	4.160
245	Experiment No. 315	22.61	8.58	43.99	24.82	5.050
246	Experiment No. 316	23.13	13.13	38.92	24.82	5.160
247	Experiment No. 317	25.34	15.26	32.59	26.81	5.360
252	Experiment No. 318	17.94	5.31	56.28	20.47	4.290
253	Experiment No. 319	21.00	11.65	46.38	20.97	4.410
254	Experiment No. 320	18.67	6.00	51.76	23.57	3.990
261	Experiment No. 321	19.50	6.44	57.06	17.00	4.220
262	Experiment No. 322	17.86	13.98	51.14	17.02	4.470
263	Experiment No. 323	19.13	8.25	52.68	19.94	4.170

TABLE 5.—*Amount, specific gravity, and nitrogen of urine from digestion experiments with hard and soft wheat breads.*

Sample No.	Subject No.	Whence obtained.	Total amount voided.	Specific gravity.	Nitrogen.
		Experiments with hard wheat:			
		Experiment No. 242—	*Grams.*		*Per cent.*
166	1	First day	1,368.0	1.026	1.58
169	1	Second day	1,350.0	1.023	1.45
172	1	Third day	1,463.5	1.027	1.65
175	1	Fourth day	1,326.0	1.029	1.74
		Experiment No. 243—			
167	2	First day	1,805.0	1.016	.88
170	2	Second day	2,112.0	1.015	.95
173	2	Third day	2,298.0	1.015	1.00
176	2	Fourth day	2,248.0	1.017	.98
		Experiment No. 244—			
168	3	First day	1,991.0	1.020	1.35
171	3	Second day	1,720.0	1.021	1.41
174	3	Third day	1,679.0	1.025	1.72
177	3	Fourth day	1,947.0	1.028	1.45
		Experiment No. 245—			
183	1	First day	1,270.0	1.030	1.82
186	1	Second day	1,210.0	1.030	1.79
189	1	Third day	1,212.0	1.030	1.84
192	1	Fourth day	1,102.0	1.028	1.88
		Experiment No. 246—			
184	2	First day	1,943.0	1.015	1.03
187	2	Second day	1,732.0	1.015	1.01
190	2	Third day	2,188.0	1.015	.95
193	2	Fourth day	2,368.0	1.014	.99
		Experiment No. 247—			
185	3	First day	1,851.0	1.024	1.39
188	3	Second day	1,581.0	1.025	1.72
191	3	Third day	1,614.5	1.027	1.75
194	3	Fourth day	1,338.0	1.027	1.94
		Experiment No. 248—			
200	1	First day	1,124.0	1.027	1.77
204	1	Second day	1,077.0	1.031	2.10
207	1	Third day	1,068.0	1.030	1.90
210	1	Fourth day	1,110.0	1.029	2.04
		Experiment No. 249—			
201	2	First day	1,943.0	1.014	1.02
205	2	Second day	1,698.0	1.015	1.00
208	2	Third day	2,182.0	1.015	.97
211	2	Fourth day	2,023.0	1.014	.97
		Experiment No. 250—			
203	3	First day	1,123.0	1.028	1.82
206	3	Second day	1,242.0	1.026	1.81
209	3	Third day	1,601.0	1.022	1.56
212	3	Fourth day	2,463.0	1.016	1.07
		Experiments with soft wheat:			
228	1	Experiment No. 309	6,023.1	1.016	1.10
229	2	Experiment No. 310	4,296.2	1.020	1.50
230	3	Experiment No. 311	4,486.2	1.019	1.31
236	1	Experiment No. 312	5,652.9	1.019	1.21
237	2	Experiment No. 313	5,201.7	1.020	1.41
238	3	Experiment No. 314	4,115.6	1.022	1.48
248	1	Experiment No. 315	7,317.4	1.016	1.19
249	2	Experiment No. 316	6,556.6	1.019	1.41
250	3	Experiment No. 317	4,747.6	1.020	1.39
255	1	Experiment No. 318	7,889.1	1.016	1.07
256	2	Experiment No. 319	6,910.1	1.020	1.47
257	3	Experiment No. 320	5,476.6	1.021	1.61
264	1	Experiment No. 321	5,210.1	1.020	1.41
265	2	Experiment No. 322	4,532.0	1.020	1.16
266	3	Experiment No. 323	4,508.8	1.022	1.80

EXPERIMENTAL METHODS.

The methods followed in all of the experiments here reported are practically identical with those described in detail in the previous publication[a] already referred to, and need only be briefly outlined.

The bread from the different sorts of flour was eaten with milk; the amount of either was not limited, but the quantities eaten at each meal were recorded. The separations of the feces were made by means of charcoal taken with a meal of bread and milk, which gives feces of a characteristic color and consistency. The digestibility of the nutrients of the diet as a whole was taken as the difference between the amounts in the food and those in the feces, no attempt being made to determine the metabolic products of the feces.[a]

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 101.

In order to compute the digestibility of the nutrients of the bread alone, it was assumed that 97 per cent of the protein, 95 per cent of the fat, and 98 per cent of the carbohydrates of milk were digested. The undigested nutrients of the milk as calculated by the use of these factors subtracted from the nutrients of the total feces give the estimated undigested nutrients from bread, which, subtracted from the total nutrients of the bread, give the digestible nutrients in bread. The latter, divided by the total nutrients in the bread, give the coefficients of digestibility of bread alone.

The values used for the digestibility of the nutrients of milk have been deduced from the results of a large number of digestion experiments with milk. Even if, in the experiments here reported, the digestibility of the milk nutrients varied from these assumed coefficients, the figures for the digestibility of the nutrients of the different kinds of bread are still strictly comparable because the same factors for milk were used in all cases.

As has been already explained,[b] the energy of the estimated feces from bread alone was computed by proportion from the energy of the total feces. The ratio of the heat of combustion of the bread feces as computed by factors to the actual energy was assumed to be the same as the ratio of the computed energy of total feces to the heat of combustion as determined.

Although the energy of the urine was determined, in the calculation of the availability of the energy of the total food and of the bread alone, it was assumed, for the sake of uniformity with experiments previously reported, that 1.25 calories of energy would appear in the urine for every gram of digestible protein in the total food or in the bread alone. For the sake of making an approximate estimate of the available energy in those experiments where the digestibility of the bread fat could not be computed, it was assumed that 90 per cent of the fat of the bread was digestible. The results thus found would probably be below rather than above what was actually the case.

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[a] It should be observed that the results thus obtained do not represent actual digestibility. The true digestibility could be found by subtracting from the ingredients of the food the corresponding ingredients of the feces that come only from undigested portions of the food. But no satisfactory method has been found for separating these from the metabolic products in the feces, which consist largely of the residues of the digestive juices that have not been reabsorbed. These latter represent the cost of digestion as expressed in terms of food ingredients. What the results of these experiments do represent, therefore, is the proportions of the food, or of the several ingredients, that are available to the body for purposes other than digestion itself. In accordance with common usage, however, the term digestibility, which indicates the apparent digestibility, has been employed here; the term availability is sometimes used to express the same idea.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 22.

As in the preceding experiments, the balance of income and outgo of nitrogen was learned by determining the daily amounts ingested in the food and excreted in the urine and feces. In the experiments with soft winter wheat in 1901–2 determinations were also made of the phosphoric acid in the samples of food, feces, and urine. Such data, however, are reserved for further study.

The particular difference between the digestion experiments given here and those formerly reported is in the length of the experimental period, this being four days long here and only two in the earlier experiments. The longer experimental period is believed to be preferable, because it is generally considered that there is less danger of error due to uncontrollable factors that may vitiate the results in a short digestion period.

As is well known, the results obtained from a digestion experiment are not absolute, but only relative. But inasmuch as in the digestion experiments reported in this bulletin the object is to determine the relative rather than the absolute digestibility of three different kinds of bread, it is believed that the results obtained are satisfactory for this purpose, because whatever error may be introduced in one experiment is introduced alike in all of any given series, since the conditions were kept uniform throughout the series. While the results of a single digestion experiment are open to criticism, the results obtained from a series of experiments are much less so and are of value in determining whether one food is more digestible than another under similar experimental conditions. Hence in discussing the results obtained from these digestion experiments they are considered in relation to one another rather than alone.

DETAILS OF THE DIGESTION EXPERIMENTS WITH BREAD FROM DIFFERENT GRADES OF HARD SPRING WHEAT FLOUR.

The details of the digestion experiments with hard wheat products are given in the following pages. Nine digestion experiments, each of four days' (or twelve meals') duration were made with three different subjects. In every case the diet consisted of bread and milk, and all of the experiments were conducted in the same manner, except that bread made from a different kind of flour was used in each series. In making the bread no shortening or milk was used, but simply yeast, flour, salt, and water.

The subjects were university students who spent from three to four hours each day at light muscular work out of doors. All had served as subjects in former digestion experiments and were thoroughly familiar with the requirements of such work.

The experiments were practically made in triplicate—that is, the same kind of an experiment was made with each of three subjects at the same time. The order in which they were conducted was as follows: The first series of experiments (with entire-wheat bread) extended from April 17 to April 20, inclusive; the second series (with graham bread) from April 23 to April 26, inclusive; and the third series (with bread from standard patent flour) from May 1 to May 4, inclusive. The experiments were taken up in this order because of the difficulty experienced in previous experiments with a graham bread and milk diet. It was believed that the investigation could be conducted to better advantage by having the graham bread experiment between the others, rather than at the beginning or close of the series. The four days' diet of graham bread and milk caused a slight irritation of the digestive tract and a slight attack of gastritis with two of the subjects.

The following tables, Nos. 6 to 14, and the accompanying data show the kind of food consumed, the subject experimented upon, the body weight at the beginning and at the close of the experiment, and the date and duration. Then follow statistics of the total nutrients in the food and the feces, and the heat of combustion of each, and after each of the tables statistics are given of the income and outgo of nitrogen during the experiment.

DIGESTION EXPERIMENT NO. 242.

Kind of food.—Milk, and bread made from entire-wheat flour.

Subject.—University student No. 1, 22 years old, employed about four hours per day at manual labor.

Weight.—At the beginning of the experiment, 168 pounds; at the close, 168 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 17, 1901.

TABLE 6.—*Results of digestion experiment No. 242.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
164	Bread	3,550.0	330.9	6.7	1,730.7	27.3	8,998
165	Milk	9,950.0	323.4	378.1	431.8	79.6	6,965
	Total		654.3	384.8	2,162.5	106.9	15,963
178	Feces (water free)	214.0	64.7	26.2	73.7	49.4	992
	Estimated feces from food other than bread		9.7		8.6		
	Estimated feces from bread		55.0		65.1		
	Total amount digested		589.6	358.6	2,088.8	57.5	14,971
	Estimated digestible nutrients in bread		275.9		1,665.6		
	Coefficients of digestibility of total food	*Per cent*	*Per cent.* 90.1	*Per cent.* 93.2	*Per cent.* 96.6	*Per cent.* 53.8	*Per cent.* 93.8
	Estimated coefficients of digestibility of bread		83.4		96.2		[a] 93.0
	Proportion of energy actually available to body:						
	In total food						88.2
	In bread alone						[a] 89.1

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 5,508 grams urine, containing 88.42 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 27.47 grams; outgo in urine, 22.10 grams and in feces, 2.59 grams, implying a gain of 2.78 grams nitrogen, corresponding to 17.4 grams protein.

DIGESTION EXPERIMENT NO. 243.

Kind of food.—Milk, and bread made from entire-wheat flour.

Subject.—University student No. 2, 22 years old, employed about four hours per day at manual labor.

Weight.—At the beginning of the experiment, 156 pounds; at the close, 155 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 17, 1901.

TABLE 7.—*Results of digestion experiment No. 243.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
164	Bread	3,101.0	289.0	5.9	1,511.8	23.9	7,860
165	Milk	12,310.0	400.1	467.8	534.3	98.5	8,617
	Total	....	689.1	473.7	2,046.1	122.4	16,477
179	Feces (water free)	180.0	51.1	13.4	63.7	51.9	733
	Estimated feces from food other than bread	....	12.0	....	10.7	....	....
	Estimated feces from bread	....	39.1	....	53.0	....	....
	Total amount digested	....	638.0	460.3	1,982.4	70.5	15,744
	Estimated digestible nutrients in bread	....	249.9	....	1,458.8	....	....
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	....	92.6	97.2	96.9	57.6	95.6
	Estimated coefficients of digestibility of bread	....	86.5	....	96.5	....	[a]90.4
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	90.7
	In bread alone	....	....	....	....	....	[a]90.0

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 8,463 grams urine, containing 80.95 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 28.68 grams; outgo in urine, 20.24 grams, and in feces, 2.09 grams, implying a gain of 6.35 grams nitrogen, corresponding to 39.7 grams protein.

DIGESTION EXPERIMENT NO. 244.

Kind of food.—Milk, and bread made from entire-wheat flour.

Subject.—University student No. 3, 24 years old, employed about four hours per day at manual labor.

Weight.—At the beginning of the experiment, 161 pounds; at the close, 160 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 17, 1901.

TABLE 8.—*Results of digestion experiment No. 244.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
164	Bread	3,760.0	350.4	7.1	1,833.1	28.9	9,530
165	Milk	14,843.0	482.4	564.0	644.2	118.8	10,390
	Total		832.8	571.1	2,477.3	147.7	19,920
180	Feces (water free)	215.1	53.8	16.0	88.9	56.4	936
	Estimated feces from food other than bread		14.5		12.9		
	Estimated feces from bread		39.3		76.0		
	Total amount digested		779.0	555.1	2,388.4	91.3	18,984
	Estimated digestible nutrients in bread		311.1		1,757.1		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		93.5	97.2	96.4	61.8	95.3
	Estimated coefficients of digestibility of bread		88.8		95.9		[a] 94.3
	Proportion of energy actually available to body:						
	In total food						90.4
	In bread alone						[a] 90.2

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 7,337 grams urine, containing 108.24 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 34.66 grams; outgo in urine, 27.06 grams, and in feces, 2.15 grams, implying a gain of 5.45 grams nitrogen, corresponding to 34.1 grams protein.

DIGESTION EXPERIMENT NO. 245.

Kind of food.—Milk, and bread made from graham flour.

Subject.—University student No. 1.

Weight.—At the beginning of the experiment, 168 pounds; at the close, 167 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 23, 1901.

TABLE 9.—*Results of digestion experiment No. 245.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories*
182	Bread	3,342.0	318.8	9.7	1,540.7	46.5	8,337
181	Milk	10,207.0	319.5	408.3	480.8	90.8	7,614
	Total	....	638.3	418.0	2,021.5	137.3	15,951
195	Feces (water free)	300.1	69.8	26.1	150.5	53.7	1,325
	Estimated feces from food other than bread	....	9.6	20.4	9.6	....	302
	Estimated feces from bread	....	60.2	5.7	140.9	....	1,023
	Total amount digested	....	568.5	391.9	1,871.0	83.6	14,626
	Estimated digestible nutrients in bread	....	258.6	4.0	1,399.8	....	7,314
	Coefficients of digestibility of total food	*Per cent.*	*Per cent.* 89.1	*Per cent.* 93.8	*Per cent.* 92.6	*Per cent.* 60.9	*Per cent.* 91.7
	Estimated coefficients of digestibility of bread	....	81.1	41.2	90.9	....	87.7
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	87.2
	In bread alone	....	....	....	....	....	83.9

During this experiment the subject eliminated 4,794 grams urine, containing 87.79 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 26.74 grams; outgo in urine, 21.95 grams, and in feces 3.79 grams, implying a gain of 1 gram nitrogen, corresponding to 6.3 grams protein.

DIGESTION EXPERIMENT NO. 246.

Kind of food.—Milk, and bread made from graham flour.

Subject.—University student No. 2.

Weight.—At the beginning of the experiment, 154 pounds; at the close, 152.7 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 23, 1901.

TABLE 10.—*Results of digestion experiment No. 246.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
182	Bread	2,855.0	272.4	8.3	1,316.2	39.7	7,123
181	Milk	10,568.0	330.8	422.7	497.8	94.1	7,883
	Total	....	603.2	431.0	1,814.0	133.8	15,006
196	Feces (water free)	259.0	60.4	14.5	123.3	60.8	1,026
	Estimated feces from food other than bread	....	9.9	....	10.0	....	....
	Estimated feces from bread	....	50.5	....	113.3	....	....
	Total amount digested	....	542.8	416.5	1,690.7	73.0	13,980
	Estimated digestible nutrients in bread	....	221.9	....	1,202.9	....	....

Table 10.—*Results of digestion experiment No. 246*—Continued.

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		90.0	96.6	93.2	54.6	93.2
	Estimated coefficients of digestibility of bread		81.5		91.4		[a] 88.9
	Proportion of energy actually available to body:						
	In total food						88.6
	In bread alone						[a] 85.1

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 8,231 grams urine, containing 81.73 grams nitrogen. The average nitrogen balance per day was, therefore, as follows: Income in food, 25.16 grams; outgo in urine, 20.43 grams, and in feces, 2.94 grams, implying a gain of 1.79 grams nitrogen, corresponding to 11.2 grams protein.

DIGESTION EXPERIMENT NO. 247.

Kind of food.—Milk, and bread made from graham flour.

Subject.—University student No. 3.

Weight.—At the beginning of the experiment, 161 pounds; at the close, 157 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 23, 1901.

Table 11.—*Results of digestion experiment No. 247.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
182	Bread	3,440.0	328.2	10.0	1,585.9	47.8	8,583
181	Milk	12,475.0	390.5	499.0	587.6	111.0	9,306
	Total		718.7	509.0	2,173.5	158.8	17,889
197	Feces (water free)	267.7	58.0	17.2	135.1	57.4	1,116
	Estimated feces from food other than bread		11.7		11.7		
	Estimated feces from bread		46.3		123.4		
	Total amount digested		660.7	491.8	2,038.4	101.4	16,773
	Estimated digestible nutrients in bread		281.9		1,462.5		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		91.9	96.6	93.8	63.9	93.8
	Estimated coefficients of digestibility of bread		85.9		92.2		[a] 90.3
	Proportion of energy actually available to body:						
	In total food						89.2
	In bread alone						[a] 86.2

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 6,385 grams urine, containing 107.13 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 30.01 grams; outgo in urine, 26.78 grams, and in feces, 2.32 grams, implying a gain of 0.91 grams nitrogen, corresponding to 5.7 grams protein.

DIGESTION EXPERIMENT NO. 248.

Kind of food.—Milk, and bread made from straight patent flour.

Subject.—University student No. 1.

Weight.—At the beginning of experiment, 164 pounds; at the close, 164 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast May 1, 1901.

TABLE 12.—*Results of digestion experiment No. 248.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
199	Bread	2,575.0	248.0	1.0	1,314.9	12.9	6,680
198	Milk	10,583.0	321.7	404.3	509.0	78.3	7,715
	Total	....	569.7	405.3	1,823.9	91.2	14,395
213	Feces (water free)	152.0	45.5	26.5	38.0	41.9	717
	Estimated feces from food other than bread	....	9.6	20.2	10.2	....	309
	Estimated feces from bread	....	35.9	....	27.8	....	....
	Total amount digested	....	524.2	378.8	1,785.9	49.3	13,678
	Estimated digestible nutrients in bread	....	212.1	....	1,287.1	....	....
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	....	92.0	93.5	97.9	54.1	95.0
	Estimated coefficients of digestibility of bread	....	85.5	....	97.9	....	[a]94.8
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	90.5
	In bread alone	....	....	....	....	....	[a]90.9

[a] Estimated on the assumption that 90 per cent of the fat in bread is digestible.

During this experiment the subject eliminated 4,378 grams urine, containing 85.44 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 23.79 grams; outgo in urine, 21.38 grams, and in feces, 1.82 grams, implying a gain of 0.59 gram nitrogen, corresponding to 3.7 grams protein.

DIGESTION EXPERIMENT NO. 249.

Kind of food.—Milk, and bread made from straight patent flour.

Subject.—University student No. 2.

Weight.—At the beginning of the experiment, 152 pounds; at the close, 151½ pounds.

Duration.—Four days, with twelve meals, beginning with breakfast May 1, 1901.

TABLE 13.—*Results of digestion experiment No. 249.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
199	Bread	2,790.0	268.7	1.2	1,424.6	13.9	7,237
198	Milk	11,717.0	356.2	447.6	563.6	86.7	8,542
	Total		624.9	448.8	1,988.2	100.6	15,779
214	Feces (water free)	146.8	41.9	16.8	38.8	49.3	626
	Estimated feces from food other than bread		10.7		11.3		
	Estimated feces from bread		31.2		27.5		
	Total amount digested		583.0	432.0	1,949.4	51.3	15,153
	Estimated digestible nutrients in bread		237.5		1,397.1		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		93.3	96.3	98.1	51.0	96.0
	Estimated coefficients of digestibility of bread		88.4		98.1		[a]95.5
	Proportion of energy actually available to body:						
	In total food						91.4
	In bread alone						[a]91.4

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 7,846 grams urine, containing 77.52 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 26.05 grams; outgo in urine, 19.38 grams, and in feces, 1.68 grams, implying a gain of 4.99 grams nitrogen, corresponding to 31.2 grams protein.

DIGESTION EXPERIMENT NO. 250.

Kind of food.—Milk, and bread made from straight patent flour.

Subject.—University student No. 3.

Weight.—At the beginning of the experiment, 152 pounds; at the close, 155 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast May 1, 1901.

TABLE 14.—*Results of digestion experiment No. 250.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
217	Bread	3,080.0	300.0	8.0	1,605.3	15.7	8,152
216	Milk	13,055.0	441.3	541.8	596.6	99.2	9,713
	Total		741.3	549.8	2,201.9	114.9	17,865
215	Feces (water free)	167.0	40.0	15.5	60.9	50.6	777
	Estimated feces from food other than bread		13.2		11.9		
	Estimated feces from bread		26.8		49.0		
	Total amount digested		701.3	534.3	2,141.0	64.3	17,088
	Estimated digestible nutrients in bread		273.2		1,556.3		

TABLE 14.—*Results of digestion experiment No. 250*—Continued.

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	....	94.6	97.2	97.2	56.0	95.7
	Estimated coefficients of digestibility of bread	....	91.1	....	97.0	....	[a]94.5
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	90.8
	In bread alone	....	....	....	....	....	[a]90.3

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 6,439 grams urine, containing 94.25 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 30.76 grams; outgo in urine, 23.56 grams, and in feces, 1.60 grams, implying a gain of 5.60 grams nitrogen, corresponding to 35.0 grams protein.

SUMMARY OF RESULTS OBTAINED WITH HARD SPRING WHEAT PRODUCTS.

The following tables summarize the results of the digestion experiments with hard spring wheat products reported in the foregoing pages. The results are given for the whole ration in Table 15 and computed for the different sorts of bread alone in Table 16. For purposes of comparison, the results obtained in previous experiments in this laboratory are also included, as well as the average digestibility of the different kinds of bread as shown by the result of all the experiments.

TABLE 15.—*Summary of digestion experiments with hard spring wheat; digestibility of nutrients and availability of energy of total food.*

Experiment No.	Subject No.	Kind of food.	Protein.	Fat.	Carbohydrates.	Energy.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
242	1	Milk and entire wheat bread	90.1	93.2	96.6	89.2
243	2	.....do	92.6	97.2	96.9	90.7
244	3	.....do	93.5	97.2	96.4	90.4
		Average of 3	92.1	95.9	96.6	90.1
		Average of 3 (1899–1900)	89.7	91.7	95.1	88.5
		Average of 6	90.9	93.8	95.8	89.3
245	1	Milk and graham bread	89.1	93.8	92.6	87.2
246	2	.....do	90.0	96.6	93.2	88.6
247	3	.....do	91.9	96.6	93.8	89.2
		Average of 3	90.3	95.7	93.2	88.3
		Average of 3 (1899–1900)	88.2	91.1	91.1	86.0
		Average of 6	89.3	93.4	92.2	87.2
248	1	Milk and white bread (standard patent)	92.0	93.5	97.9	90.5
249	2	.....do	93.3	96.3	98.1	91.4
250	3	.....do	94.6	97.2	97.2	90.8
		Average of 3	93.3	95.7	97.7	90.9
		Average of 3 (1899–1900)	91.4	92.4	97.6	90.3
		Average of 6	92.4	94.5	97.7	90.6

TABLE 16.—*Summary of digestion experiments with hard spring wheat; digestibility of nutrients and availability of energy of bread alone.*

Experiment No.	Subject No.	Kind of food.	Protein.	Carbohydrates.	Energy.
			Per cent.	*Per cent.*	*Per cent.*
242	1	Entire wheat bread	83.4	96.2	89.1
243	2	.....do	86.5	96.5	90.0
244	3	.....do	88.8	95.9	90.2
		Average of 3	86.2	96.2	89.8
		Average of 3 (1899–1900)	80.4	94.1	85.5
		Average of 6	83.3	95.1	87.6
245	1	Graham bread	81.1	90.9	83.9
246	2	.....do	81.5	91.4	85.1
247	3	.....do	85.9	92.2	86.2
		Average of 3	82.8	91.5	85.1
		Average of 3 (1899–1900)	77.6	88.4	80.7
		Average of 6	80.2	90.0	82.9
248	1	White bread (standard patent)	85.5	97.9	90.9
249	2	.....do	88.4	98.1	91.4
250	3	.....do	91.1	97.0	90.3
		Average of 3	88.3	97.7	90.9
		Average of 3 (1899–1900)	85.3	97.5	90.1
		Average of 6	86.8	97.6	90.5

It will be observed that the average coefficients of digestibility of the protein and carbohydrates and of the available energy in the ration consisting of milk and bread made from straight patent flour ground from hard spring wheat were larger than in the rations of milk and entire-wheat bread or milk and graham bread from the same lot of wheat. Considering the calculated results for bread alone, in the experiments here reported it appears that in the graham bread the average digestibility of the protein is 82.8 per cent; of the carbohydrates, 91.5 per cent, and the available energy is 85.1 per cent. The digestion coefficients for the graham bread are lower than for either the entire-wheat bread or the straight patent flour bread. In the case of the bread from entire-wheat flour 86.2 per cent of the protein was digested, and in the straight patent flour bread 88.3 per cent, while 96.2 per cent of the carbohydrates in the entire-wheat flour bread and 97.7 per cent of those in the bread from the straight patent flour were found to be digestible.

An examination of the tables also shows in each of the series a range of from 4 to nearly 6 per cent in the digestion coefficients of each of the nutrients. This is probably due to differences in the digestive powers of the three subjects. Thus, for example, subject No. 3 digested the bread made from straight patent flour, entire-wheat flour, and graham flour more completely than either subject No. 1 or No. 2. While individual differences are observed in the three series of experiments, in every case it appears that each subject digested the nutrients in the straight patent flour bread more completely than the nutrients in either the entire-wheat bread or the graham bread.

Hence the results for the average digestibility in the different series of experiments are strictly comparable.

The tables also compare the results of the experiments reported in this bulletin and those formerly reported.[a] It will be observed that although the digestion coefficients are somewhat larger in the experiments here reported than in those of 1899–1900, there is a general similarity of results. In both series the nutrients of the bread from standard patent flour are the most and those of graham the least digestible, the entire-wheat flour bread being between the two. These experiments are regarded as strictly comparable. Considering the two years' investigations as a whole, six subjects were employed and eighteen separate digestion experiments were made.

Table 16 gives the average digestibility of the nutrients and availability of the energy in the three kinds of bread as shown by the results of the two series. It is believed that these figures show, with a fair degree of accuracy, the comparative digestibility of the protein and carbohydrates and availability of energy in bread made from the three kinds of flour when milled from the same lot of hard spring wheat and consumed under similar conditions. The results, considered as a whole, show that the protein in the straight patent flour bread is 6.6 per cent more digestible than that of the graham bread, while the carbohydrates are 5.6 per cent more digestible. The amount of available energy in the straight-flour bread is also greater by 7.5 per cent than that in the graham bread.

In Table 17 the total and digestible protein and carbohydrates and total and available energy in the three different kinds of flour as milled are given. These values for digestible nutrients and available energy were obtained by multiplying the percentage of total nutrients and energy by the coefficients given in Table 17.

TABLE 17.—*Percentages of digestible protein and carbohydrates, and available energy in entire-wheat, graham, and straight patent flours as milled.*

Grade of flour from hard spring wheat.	Protein (N×5.70).		Carbohydrates.		Energy per gram.	
	Total.	Digestible.	Total.	Digestible.	Total.	Available.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Straight patent	13.60	12.01	72.04	70.31	3.861	3.510
Entire wheat	13.72	11.83	70.09	67.43	3.877	3.481
Graham	14.21	11.77	68.55	62.62	3.971	3.379

There was a somewhat larger amount of digestible protein in the straight patent flour than in either the graham or entire-wheat flour. In the straight patent flour there was 70.31 per cent of digestible carbohydrates, in the entire-wheat flour 67.43 per cent, and in the graham flour 62.62 per cent; that is, the carbohydrates of the straight patent flour were much more digestible than those of either the entire wheat or graham flour. The amount of available energy of the straight patent flour is also larger than that of either the graham or entire-wheat flour.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 33.

On comparing the figures in this table with those previously reported[a] it will be observed that the results for protein here given are higher. This is due to two facts already pointed out, namely, that the percentage of protein in the wheat employed in these experiments was higher, and the coefficients of digestibility were larger. The significance of the results, however, is the same in both cases. Briefly stated, the results of all of the experiments with hard spring wheat show that the digestible protein and carbohydrates, as well as the amount of available energy, are greater in the standard patent flour than in either the graham or entire-wheat flour.

No marked variations in the balance of income and outgo of nitrogen were observed in the different periods except such as were due to differences in the amounts consumed. In other words, judged by the data regarding the metabolism of nitrogen, the three sorts of breads served the body equally well.

The results of these experiments confirm those of earlier work with hard-wheat flours, and show that when breads made from straight patent flour, entire-wheat flour, and graham flour, milled from the same lot of hard spring wheat, are fed under uniform experimental conditions to men, there is a larger amount of digestible protein and carbohydrates and available energy in the patent flour than in either the entire-wheat or graham flour, although judged by composition the graham flour contains the most and the patent flour the least total protein. The greater digestibility of the protein and carbohydrates of the patent flour is regarded as due in part at least to the fineness of division of the flour particles, or, in other words, to the fact that a considerable portion of the nutrients in the graham and entire-wheat flours are present in comparatively large particles, which resist the action of the digestive fluids and so escape digestion. It has also been suggested that the cell walls in the layer of the grain directly under the bran are more resistant to digestive juices than the walls of cells in the interior of the kernel (see pp. 48, 49). Thus while there is actually somewhat more protein, pound for pound, in graham or entire-wheat than in patent flour, the body obtains less protein and energy from the coarser than it does from the finer flour, and whatever is gained in composition by adding the bran or germ is offset by the loss in digestibility.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 33.

DETAILS OF THE DIGESTION EXPERIMENTS WITH BREAD FROM DIFFERENT GRADES OF SOFT WINTER WHEAT FLOUR.

In order to determine whether the results obtained with bread from hard-wheat flours would be the same with flours from wheat of a different character, fifteen digestion experiments were made with bread from graham, entire-wheat, and standard patent flours milled from soft winter wheat. The results of these experiments are reported on the following pages.

Two sets of experiments were made. In one set, comprising the first six of the following experiments, the flours used were prepared from the same lot of Indiana soft winter wheat by a milling company of Goshen, Ind. Only two kinds of flour were used in these six experiments, one being a standard patent grade similar to but not quite the same as the same grade of flour used in the experiments with hard wheat; the other was a so-called entire-wheat flour, but was somewhat coarser than this grade of flour prepared from hard wheat. In the second set of experiments three grades of flours were used, all ground from the same lot of Michigan soft winter wheat by a milling company of North Lansing, Mich.

The experiments were made by the same methods as were followed in earlier work with hard-wheat flours. The experiment proper was preceded by a preliminary meal of bread and milk, charcoal being used to mark the separation of the feces. The experimental period continued three days in the experiments with the Indiana flours, and four days with the Michigan flours. The subjects were young men in good health, designated as Nos. 1, 2, and 3. They were employed at farm labor, office, and university work. One subject, No. 1, had been employed in the digestion work of 1900 and 1901 as subject No. 3. The subjects were allowed a diet of bread and milk, unrestricted as to amount, the quantities consumed at each meal being carefully weighed. The different series of experiments in which graham, entire-wheat, and straight-grade flours were used were alike in all respects except as regards the bread. The four days' diet of milk and graham bread proved to be rather laxative. It was observed that the subjects who were employed at the severest labor had a decided preference for the bread made from the straight and mixed grade flours, while the one employed at office and university work did not have so pronounced a preference. In no case was the graham bread preferred.

Tables 18 to 32 record the data of the several digestion experiments.

DIGESTION EXPERIMENT NO. 309.

Kind of food.—Milk, and bread made from straight-grade flour.

Subject.—Man No. 1; age, 25 years; employed at office work.

Weight.—At the beginning of the experiment, 161.25 pounds; at the close, 162 pounds.

Duration.—Three days, with nine meals, beginning with breakfast April 9, 1902.

TABLE 18.—*Results of digestion experiment No. 309.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
223	Bread	2,950.0	236.3	17.7	1,513.9	15.0	7,994
224	Milk	9,850.0	326.0	431.4	445.2	77.8	7,683
	Total	....	562.3	449.1	1,959.1	92.8	15,677
225	Feces (water free)	166.0	23.4	28.3	74.9	39.4	835
	Estimated feces from food other than bread	....	9.8	21.6	8.9	....	347
	Estimated feces from bread	....	13.6	6.7	66.0	....	488
	Total amount digested	....	538.9	420.8	1,884.2	53.4	14,842
	Estimated digestible nutrients in bread	....	222.7	11.0	1,447.9	....	7,506
	Coefficients of digestibility of total food	*Per cent.*	*Per cent.* 95.8	*Per cent.* 93.7	*Per cent.* 96.2	*Per cent.* 57.5	*Per cent.* 94.7
	Estimated coefficients of digestibility of bread	....	94.2	62.1	95.6	....	93.9
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	90.4
	In bread alone	....	....	....	....	....	90.4

During this experiment the subject eliminated 6,023 grams urine, containing 66.25 grams nitrogen. The nitrogen balance per day was therefore as follows: Income in food, 31.20 grams; outgo in urine, 22.08 grams, and in feces, 1.25 grams, implying a gain of 7.87 grams nitrogen, corresponding to 49.2 grams protein.

DIGESTION EXPERIMENT NO. 310.

Kind of food.—Milk, and bread made from straight-grade flour.

Subject.—Man No. 2; age, 25 years; university student; employed at average farm labor four hours per day.

Weight.—At the beginning and close of the experiment, 163.75 pounds.

Duration.—Three days, with nine meals, beginning with breakfast April 9, 1902.

TABLE 19.—*Results of digestion experiment No. 310.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
223	Bread	2,860.0	229.0	17.2	1,467.7	14.6	7,751
224	Milk	7,850.0	259.8	343.8	354.8	62.0	6,123
	Total	....	488.8	361.0	1,822.5	76.6	13,874
226	Feces (water free)	147.0	32.1	23.3	57.2	34.4	779
	Estimated feces from food other than bread	....	7.8	17.2	7.1	....	287
	Estimated feces from bread	....	24.3	6.1	50.1	....	492

Table 19.—*Results of digestion experiment No. 310*—Continued.

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
	Total amount digested	....	456.7	337.7	1,765.3	42.2	13,095
	Estimated digestible nutrients in bread	....	204.7	11.0	1,417.6	....	7,259
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	....	93.4	93.5	96.9	55.1	94.4
	Estimated coefficients of digestibility of bread	....	89.4	64.4	96.6	....	93.6
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	90.3
	In bread alone	....	....	....	....	....	90.4

During this experiment the subject eliminated 4,296 grams urine, containing 64.61 grams nitrogen. The nitrogen balance per day was therefore as follows: Income in food, 27.25 grams; outgo in urine, 21.54 grams, and in feces, 1.71 grams, implying a gain of 4 grams nitrogen, corresponding to 25 grams protein.

DIGESTION EXPERIMENT NO. 311.

Kind of food.—Milk, and bread made from straight-grade flour.

Subject.—Man No. 3; 21 years of age, employed at average farm labor.

Weight.—At the beginning of the experiment, 151.75 pounds; at the close, 150.5 pounds.

Duration.—Three days, with nine meals, beginning with breakfast April 9, 1902.

Table 20.—*Results of digestion experiment No. 311.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
223	Bread	2,572.0	206.0	15.4	1,319.9	13.1	6,970
224	Milk	6,771.0	224.1	296.6	306.1	53.5	5,281
	Total	....	430.1	312.0	1,626.0	66.6	12,251
227	Feces (water free)	156.0	41.7	14.2	61.5	38.6	686
	Estimated feces from food other than bread	....	6.7	....	6.1	....	....
	Estimated feces from bread	....	35.0	....	55.4	....	....
	Total amount digested	....	388.4	297.8	1,564.5	28.0	11,565
	Estimated digestible nutrients in bread	....	171.0	....	1,264.5	....	....
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	....	90.3	95.5	96.2	42.0	94.4
	Estimated coefficients of digestibility of bread	....	83.0	....	95.8	....	[a] 93.5
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	90.4
	In bread alone	....	....	....	....	....	[a] 90.4

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 4,486 grams urine, containing 58.77 grams nitrogen. The nitrogen balance per day was therefore as follows: Income in food 24 grams; outgo in urine 19.59 grams, and in feces 223 grams, implying a gain of 2.18 grams nitrogen, corresponding to 13.6 grams protein.

DIGESTION EXPERIMENT NO. 312.

Kind of food.—Milk, and bread made from finely ground graham or entire-wheat flour.

Subject.—Man No. 1, as in experiment No. 309.

Weight.—At the beginning of the experiment 163.75 pounds; at the close 164 pounds.

Duration.—Three days with nine meals, beginning with breakfast April 14, 1902.

TABLE 21.—*Results of digestion experiment No. 312.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
231	Bread	3,110.0	265.3	31.7	1,539.1	45.4	8,210
232	Milk	9,500.0	315.4	443.6	444.6	73.1	7,723
	Total	....	580.7	475.3	1,983.7	118.5	15,933
233	Feces (water free)	260.3	37.3	13.9	157.4	51.7	1,130
	Estimated feces from food other than bread	....	9.4	....	8.9	....	....
	Estimated feces from bread	....	27.9	....	148.5	....	....
	Total amount digested	....	543.4	461.4	1,826.3	66.8	14,803
	Estimated digestible nutrients in bread	....	237.4	....	1,390.6	....	....
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	....	93.6	97.1	92.1	56.4	92.9
	Estimated coefficients of digestibility of bread	....	89.5	....	90.3	....	[a]90.2
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	88.6
	In bread alone	....	....	....	....	....	[a]85.2

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 5,201.7 grams urine, containing 68.23 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 32.34 grams; outgo in urine, 22.74 grams, and in feces, 1.95 grams, implying a gain of 7.65 grams nitrogen, corresponding to 47.8 grams protein.

DIGESTION EXPERIMENT NO. 313.

Kind of food.—Milk, and bread made from finely ground graham or entire-wheat flour.

Subject.—Man No. 2, as in experiment No. 310.

Weight.—At the beginning of the experiment, 164.5 pounds; at the close, 164.75 pounds.

Duration.—Three days, with nine meals, beginning with breakfast April 14, 1902.

TABLE 22.—*Results of digestion experiment No. 313.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
	Food consumed:						
231	Bread	3,070.0	261.9	31.3	1,519.3	44.8	8,105
232	Milk	9,770.0	324.4	456.3	457.2	75.2	7,943
	Total	....	586.3	487.6	1,976.5	120.0	16,048
234	Feces (water free)	294.0	49.3	30.3	164.6	49.8	1,299
	Estimated feces from food other than bread	....	9.7	22.8	9.2	....	319
	Estimated feces from bread	....	39.6	7.5	155.4	....	980
	Total amount digested	....	537.0	457.3	1,811.9	70.2	14,749
	Estimated digestible nutrients in bread	....	222.3	23.8	1,363.9	....	7,125
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	....	91.6	93.8	91.7	58.5	91.9
	Estimated coefficients of digestibility of bread	....	84.9	76.0	89.8	....	87.9
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	87.7
	In bread alone	....	....	....	....	....	84.5

During this experiment the subject eliminated 5,201.7 grams urine, containing 73.35 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 32.62 grams; outgo in urine, 24.45 grams, and in feces, 2.60 grams, implying a gain of 5.57 grams nitrogen, corresponding to 34.8 grams protein.

DIGESTION EXPERIMENT NO. 314.

Kind of food.—Milk, and bread made from finely ground graham or entire-wheat flour.

Subject.—Man No. 3, as in experiment No. 311.

Weight.—At the beginning of the experiment, 150.5 pounds; at the close, 151 pounds.

Duration.—Three days, with nine meals, beginning with breakfast April 14, 1902.

TABLE 23.—*Results of digestion experiment No. 314.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
	Food consumed:						
231	Bread	2,670.0	227.7	27.2	1,321.4	39.0	7,049
232	Milk	8,000.0	265.6	373.6	374.4	61.6	6,504
	Total	....	493.3	400.8	1,695.8	100.6	13,553
235	Feces (water free)	275.0	55.2	11.9	155.4	52.6	1,144
	Estimated feces from food other than bread	....	8.0	....	7.5	....	....
	Estimated feces from bread	....	47.2	....	147.9	....	....

TABLE 23.—*Results of digestion experiment No. 314*—Continued.

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
	Total amount digested		438.1	388.9	1,540.4	48.0	12,409
	Estimated digestible nutrients in bread		180.5		1,173.5		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		88.8	97.0	90.8	47.7	91.6
	Estimated coefficients of digestibility of bread		79.3		88.8		[a] 86.1
	Proportion of energy actually available to body:						
	In total food						87.5
	In bread alone						[a] 82.9

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 4,115.6 grams urine, containing 60.91 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 27.48 grams; outgo in urine, 20.30 grams, and in feces, 2.94 grams, implying a gain of 4.24 grams nitrogen, corresponding to 26.5 grams protein.

DIGESTION EXPERIMENT NO. 315.

Kind of food.—Milk, and bread made from straight flour.

Subject.—Man No. 1, as in experiment No. 309.

Weight.—At the beginning and close of the experiment, 166 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 28, 1902.

TABLE 24.—*Results of digestion experiment No. 315.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
	Food consumed:						
244	Bread	3,615.0	274.4	13.7	1,976.3	17.7	9,435
243	Milk	11,750.0	351.3	480.6	565.2	90.5	8,719
	Total		625.7	494.3	2,541.5	108.2	18,154
245	Feces (water free)	132.0	29.8	11.3	58.1	32.8	667
	Estimated feces from food other than bread		10.5		11.3		
	Estimated feces from bread		19.3		46.8		
	Total amount digested		595.9	483.0	2,483.4	75.4	17,487
	Estimated digestible nutrients in bread		255.1		1,929.5		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		95.2	97.7	97.7	69.7	96.3
	Estimated coefficient of digestibility of bread		93.0		97.6		[a] 97.3
	Proportion of energy actually available to body:						
	In total food						92.2
	In bread alone						[a] 93.4

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 7,317.4 grams urine, containing 87.08 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 26.09 grams; outgo in urine, 21.77 grams, and in feces, 1.19 grams, implying a gain of 3.13 grams nitrogen, corresponding to 19.6 grams protein.

DIGESTION EXPERIMENT NO. 316.

Kind of food.—Milk, and bread made from straight flour.

Subject.—Man No. 2, as in experiment No. 310.

Weight.—At the beginning and close of the experiment, 166 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 28, 1902.

TABLE 25.—*Results of digestion experiment No. 316.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
244	Bread	3,480.0	264.1	13.2	1,902.3	17.0	9,082
243	Milk	12,730.0	380.6	520.6	612.3	98.0	9,445
	Total	....	644.7	533.8	2,514.6	115.0	18,527
246	Feces (water free)	113.0	26.1	14.8	44.0	28.0	583
	Estimated feces from food other than bread	....	11.4	....	12.3	....	....
	Estimated feces from bread	....	14.7	....	31.7	....	....
	Total amount digested	....	618.6	519.0	2,470.6	87.0	17,944
	Estimated digestible nutrients in bread	....	249.4	....	1,870.6	....	....
	Coefficients of digestibility of total food	*Per cent.*	*Per cent.* 95.9	*Per cent.* 97.2	*Per cent.* 98.2	*Per cent.* 75.6	*Per cent.* 96.9
	Estimated coefficients of digestibility of bread	....	94.4	....	98.3	....	[a] 98.5
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	92.7
	In bread alone	....	....	....	....	....	[a] 95.1

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 6,556.6 grams urine, containing 92.45 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 26.81 grams; outgo in urine, 23.11 grams, and in feces, 1.05 grams, implying a gain of 2.65 grams, nitrogen, corresponding to 16.6 grams protein.

DIGESTION EXPERIMENT NO. 317.

Kind of food.—Milk, and bread made from straight flour.

Subject.—Man No. 3, as in experiment No. 311.

Weight.—At the beginning of the experiment, 151 pounds; at the close, 150.25 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast April 28, 1902.

TABLE 26.—*Results of digestion experiment No. 317.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
241	Bread	3,330.0	252.7	12.6	1,820.3	16.3	8,691
243	Milk	10,150.0	303.5	415.1	488.2	78.2	7,531
	Total	....	556.2	427.7	2,308.5	94.5	16,222
247	Feces (water free)	127.0	32.2	19.4	41.4	34.1	681
	Estimated feces from food other than bread	....	9.1	....	9.8	....	....
	Estimated feces from bread	....	23.1	....	31.6	....	....
	Total amount digested	....	524.0	408.3	2,267.1	60.4	15,541
	Estimated digestible nutrients in bread	....	229.6	....	1,788.7	....	....
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	....	94.2	95.5	98.2	63.9	95.8
	Estimated coefficients of digestibility of bread	....	90.9	....	98.2	....	[a]97.4
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	91.8
	In bread alone	....	....	....	....	....	[a]94.1

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 4,747.6 grams urine, containing 65.99 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 23.22 grams; outgo in urine, 16.50 grams, and in feces, 1.29 grams, implying a gain of 5.43 grams nitrogen, corresponding to 33.9 grams protein.

DIGESTION EXPERIMENT NO. 318.

Kind of food.—Milk, and bread made from entire-wheat flour.

Subject.—Man No. 1, as in experiment No. 309.

Weight.—At the beginning of the experiment, 167.25 pounds; at the close, 168 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast May 5, 1902.

TABLE 27.—*Results of digestion experiment No. 318.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
251	Bread	3,700.0	308.2	40.0	1,913.0	47.0	9,952
258	Milk	12,000.0	360.0	462.0	570.0	87.6	8,820
	Total	....	668.2	502.0	2,483.0	134.6	18,772
252	Feces (water free)	287.0	51.5	15.2	161.5	58.8	1,231
	Estimated feces from food other than bread	....	10.8	....	11.4	....	....
	Estimated feces from bread	....	40.7	....	150.1	....	....
	Total amount digested	....	616.7	486.8	2,321.5	75.8	17,541
	Estimated digestible nutrients in bread	....	267.5	....	1,762.9	....	....

TABLE 27.—*Results of digestion experiment No. 318*—Continued.

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		92.3	97.0	93.5	56.3	93.4
	Estimated coefficients of digestibility of bread		86.8		92.2		[a] 91.3
	Proportion of energy actually available to body:						
	In total food						89.3
	In bread alone						[a] 87.9

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 7,889.1 grams urine, containing 84.41 grams nitrogen. The total nitrogen balance for four days was therefore as follows: Income in food, 27.92 grams; outgo in urine, 21.10 grams, and in feces, 2.06 grams, implying a gain of 4.76 grams nitrogen, corresponding to 29.8 grams protein.

DIGESTION EXPERIMENT NO. 319.

Kind of food.—Milk, and bread made from entire-wheat flour.

Subject.—Man No. 2, as in experiment No. 310.

Weight.—At the beginning and close of the experiment, 167.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast May 5, 1902.

TABLE 28.—*Results of digestion experiment No. 319.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
251	Bread	3,655.0	304.5	39.5	1,889.5	46.4	9,831
258	Milk	12,380.0	371.4	476.6	588.0	90.4	9,100
	Total		675.9	516.1	2,477.5	136.8	18,931
253	Feces (water free)	302.0	63.4	35.2	140.1	63.3	1,332
	Estimated feces from food other than bread		11.1	23.8	11.8		351
	Estimated feces from bread		52.3	11.4	128.3		981
	Total amount digested		612.5	480.9	2,337.4	73.5	17,599
	Estimated digestible nutrients in bread		252.2	28.1	1,761.2		8,850
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food		90.6	93.2	94.3	53.7	92.9
	Estimated coefficients of digestibility of bread		82.8	71.1	93.2		90.0
	Proportion of energy actually available to body:						
	In total food						88.9
	In bread alone						86.8

During this experiment the subject eliminated 6,910.1 grams urine, containing 101.58 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 28.21 grams; outgo in urine, 25.39 grams, and in feces, 2.57 grams, implying a gain of 0.25 gram nitrogen, corresponding to 1.6 grams protein.

DIGESTION EXPERIMENT NO. 320.

Kind of food.—Milk, and bread made from entire-wheat flour.

Subject.—Man No. 3, as in experiment No. 311.

Weight.—At the beginning of the experiment, 150 pounds; at the close, 151.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast May 5, 1902.

TABLE 29.—*Results of digestion experiment No. 320.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
251	Bread	3,650.0	304.0	39.4	1,887.1	46.3	9,818
258	Milk	11,750.0	352.5	452.4	558.1	85.8	8,636
	Total	....	656.5	491.8	2,445.2	132.1	18,454
254	Feces (water free)	262.0	48.9	15.7	135.6	61.7	1,045
	Estimated feces from food other than bread	....	10.6	....	11.2	....	....
	Estimated feces from bread	....	38.3	....	124.4	....	....
	Total amount digested	....	607.6	476.1	2,309.6	70.4	17,409
	Estimated digestible nutrients in bread	....	265.7	....	1,762.7	....	....
	Coefficients of digestibility of total food	*Per cent.*	*Per cent.* 92.5	*Per cent.* 96.8	*Per cent.* 94.4	*Per cent.* 53.3	*Per cent.* 94.3
	Estimated coefficients of digestibility of bread	....	87.4	....	93.4	....	[a] 92.7
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	90.2
	In bread alone	....	....	....	....	....	[a] 89.4

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 5,476.6 grams urine, containing 88.17 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 27.44 grams; outgo in urine, 22.04 grams, and in feces 1.96 grams, implying a gain of 3.44 grams nitrogen, corresponding to 21.5 grams protein.

DIGESTION EXPERIMENT NO. 321.

Kind of food.—Milk, and bread made from graham flour.

Subject.—Man No. 1, as in experiment No. 309.

Weight.—At the beginning of the experiment, 169.75 pounds; at the close, 170 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast May 16, 1902.

TABLE 30.—*Results of digestion experiment No. 321.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
260	Bread	3,695.0	308.9	32.2	1,891.8	53.6	9,681
259	Milk	11,850.0	385.1	527.3	596.1	91.2	9,207
	Total	....	694.0	559.5	2,487.9	144.8	18,888
261	Feces (water free)	389.0	75.9	25.1	222.0	66.1	1,641
	Estimated feces from food other than bread	....	11.6	....	11.9	....	....
	Estimated feces from bread	....	64.3	....	210.1	....	....
	Total amount digested	....	618.1	534.4	2,265.9	78.7	17,247
	Estimated digestible nutrients in bread	....	244.6	....	1,681.7	....	....
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	....	89.1	95.5	91.1	54.4	91.3
	Estimated coefficients of digestibility of bread	....	79.2	....	88.9	....	[a]85.8
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	87.2
	In bread alone	....	....	....	....	....	[a]82.7

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 5,211 grams urine, containing 73.48 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 28.95 grams; outgo in urine, 18.37 grams, and in feces, 3.04 grams, implying a gain of 7.54 grams nitrogen, corresponding to 47.1 grams protein.

DIGESTION EXPERIMENT NO. 322.

Kind of food.—Milk, and bread made from graham flour.

Subject.—Man No. 2, as in experiment No. 310.

Weight.—At the beginning and close of the experiment, 166.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast May 16, 1902.

TABLE 31.—*Results of digestion experiment No. 322.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
260	Bread	3,455.0	288.8	30.1	1,768.9	50.1	9,052
259	Milk	11,750.0	381.9	522.9	591.0	90.5	9,130
	Total	....	670.7	553.0	2,359.9	140.6	18,182
262	Feces (water free)	387.0	69.1	54.1	197.9	65.9	1,730
	Estimated feces from food other than bread	....	11.5	26.1	11.8	....	361
	Estimated feces from bread	....	57.6	28.0	186.1	....	1,369
	Total amount digested	....	601.6	498.9	2,162.0	74.7	16,452
	Estimated digestible nutrients in bread	....	231.2	2.1	1,582.8	....	7,683

Table 31.—*Results of digestion experiment No. 322*—Continued.

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Coefficients of digestibility of total food	*Per cent.*	*Per cent.* 89.7	*Per cent.* 90.2	*Per cent.* 91.6	*Per cent.* 53.1	*Per cent.* 90.5
	Estimated coefficients of digestibility of bread	....	80.1	7.0	89.5	....	84.9
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	86.3
	In bread alone	....	....	....	....	....	81.7

During this experiment the subject eliminated 4,532 grams urine, containing 52.57 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 27.94 grams; outgo in urine, 13.14 grams, and in feces, 2.76 grams, implying a gain of 12.04 grams nitrogen, corresponding to 75.2 grams protein.

DIGESTION EXPERIMENT NO. 323.

Kind of food.—Milk, and bread made from graham flour.

Subject.—Man No. 3, as in experiment No. 311.

Weight.—At the beginning of the experiment, 151.25 pounds; at the close, 150.5 pounds.

Duration.—Four days, with twelve meals, beginning with breakfast May 16, 1902.

Table 32.—*Results of digestion experiment No. 323.*

Sample No.		Weight of material.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Food consumed:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
260	Bread	3,580.0	299.3	31.1	1,832.9	51.9	9,379
259	Milk	11,000.0	357.5	489.5	553.3	84.7	8,546
	Total	....	656.8	520.6	2,386.2	136.6	17,925
263	Feces (water free)	384.0	73.4	31.7	202.3	76.6	1,601
	Estimated feces from food other than bread	....	10.7	24.5	11.1	....	348
	Estimated feces from bread	....	62.7	7.2	191.2	....	1,253
	Total amount digested	....	583.4	488.9	2,183.9	60.0	16,324
	Estimated digestible nutrients in bread	....	236.6	23.9	1,641.7	....	8,126
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	Coefficients of digestibility of total food	....	88.8	93.9	91.5	43.9	91.1
	Estimated coefficients of digestibility of bread	....	79.0	76.8	89.6	....	86.6
	Proportion of energy actually available to body:						
	In total food	....	....	....	....	....	87.0
	In bread alone	....	....	....	....	....	83.5

During this experiment the subject eliminated 4,509 grams urine, containing 85.16 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 27.42 grams; outgo in urine, 21.29 grams, and in feces, 2.94 grams, implying a gain of 3.19 grams nitrogen, corresponding to 19.9 grams protein.

SUMMARY OF RESULTS OBTAINED WITH SOFT WINTER WHEAT PRODUCTS.

In Table 33 a summary is given of the digestibility of the nutrients and availablity of the energy of the entire food of the various digestion experiments with milk and white bread from mixed-grade flour, white bread from straight-grade flour, entire-wheat bread, and graham, all ground from soft winter wheat.

TABLE 33.—*Summary of digestion experiments with soft winter wheat; digestibility of nutrients and availability of energy of total food.*

Experiment No.	Subject No.	Kind of food.	Protein.	Fat.	Carbohydrates.	Energy.
		Experiments with Indiana wheat:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
309	1	Milk and white bread (mixed grade)...	95.8	93.7	96.2	90.4
310	2	....do	93.4	93.5	96.9	90.3
311	3	....do	90.3	95.5	96.2	90.4
		Average of 3	93.2	94.2	96.4	90.4
312	1	Milk and entire-wheat bread...........	93.6	97.1	92.1	88.6
313	2	....do	91.6	93.8	91.7	87.7
314	3	....do	88.8	97.0	90.8	87.5
		Average of 3	91.3	96.0	91.5	87.9
		Experiments with Michigan wheat:				
315	1	Milk and white bread (standard patent)	95.2	97.7	97.7	92.2
316	2	....do	95.9	97.2	98.2	92.7
317	3	....do	94.2	95.5	98.2	91.8
		Average of 3	95.1	96.8	98.0	92.2
318	1	Milk and entire-wheat bread...........	92.3	97.0	93.5	89.3
319	2	....do	90.6	93.2	94.3	88.9
320	3	....do	92.5	96.8	94.4	90.2
		Average of 3	91.8	95.7	94.1	89.5
321	1	Milk and graham bread	89.1	95.5	91.1	87.2
322	2	....do	89.7	90.2	91.6	86.2
323	3	....do	88.8	93.9	91.5	87.0
		Average of 3	89.2	93.2	91.4	86.8

The results summarized in the table show that, in general, the ration consisting of milk and white bread made from the patent grade flour was more digestible than the rations of milk and bread made from either of the other kinds of flour, also that a larger percentage of energy was available to the body in the case of white bread and milk than from the entire-wheat or graham bread and milk.

In the experiments with Indiana soft wheat individual differences as regards the ability to digest the bread and milk rations were quite pronounced with the various subjects; in the case of the white bread, a difference of about 5.5 per cent in the digestibility of the protein being observed. Subject No. 1 digested the wheat bread and also the entire-wheat bread more completely than did subject No. 2 or No. 3. With each subject, however, the digestibility of the ration with white bread was greater than that with entire wheat. In the experiments with Michigan soft wheat individual differences are noticeable, but they are less pronounced, and, as was the case with the other wheats, each subject digested the ration of white bread and milk more completely than bread made from either of the other flours.

In Table 34 the calculated digestibility of the nutrients and availability of the energy of the bread alone are given:

TABLE 34.—*Summary of digestion experiments with soft winter wheat; digestibility of nutrients and availability of energy of bread alone.*

Experiment No.	Subject No.	Kind of food.	Protein.	Carbohydrates.	Energy.
		Experiments with Indiana wheat:	*Per cent.*	*Per cent.*	*Per cent.*
309	1	White bread (mixed grade flour)	94.2	95.6	90.4
310	2	....do	89.4	96.6	90.4
311	3	....do	83.0	95.8	90.4
		Average of 3	88.9	96.0	90.4
312	1	Entire-wheat bread	89.5	90.3	85.2
313	2	....do	84.9	89.8	84.5
314	3	....do	79.3	88.8	82.9
		Average of 3	84.6	89.6	84.2
		Experiments with Michigan wheat:			
315	1	White bread (standard patent)	93.0	97.6	93.4
316	2	....do	94.4	98.3	95.1
317	3	....do	90.9	98.2	94.1
		Average of 3	92.8	98.0	94.2
318	1	Entire-wheat bread	86.8	92.2	87.9
319	2	....do	82.8	93.2	86.8
320	3	....do	87.4	93.4	89.4
		Average of 3	85.7	92.9	88.0
321	1	Graham bread	79.2	88.9	82.7
322	2	....do	80.1	89.5	81.7
323	3	....do	79.0	89.6	83.5
		Average of 3	79.4	89.3	82.6

These results are calculated, as explained on page 19, by assuming that 97 per cent of the protein and 98 per cent of the carbohydrates of the milk were digested.[a]

The average result of the experiments with flour milled from Indiana soft winter wheat shows that 88.9 per cent of the protein and 96 per cent of the carbohydrates of the white bread from mixed-grade flour were digested, and that 90.4 per cent of the energy was available. As regards the bread from entire-wheat flour, ground from the same lot of wheat, 84.6 per cent of the protein and 89.6 per cent of the carbohydrates were found to be digestible, and 84.2 per cent of the energy to be available. It will be observed, further, that with each of the subjects the nutrients of the white bread were more digestible and the energy more available than was the case with the entire-wheat bread.

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[a] It was also assumed that 95 per cent of the fat of the milk would be digested, but with this factor the digestibility of the fat of bread could be computed satisfactorily in only a few cases; therefore figures for this constituent are left out of Table 34. In all cases where the digestibility of bread fat could not be computed it was assumed, in order to estimate the available energy of the bread, that 90 per cent would be digested.

The white bread made from straight-grade flour milled from Michigan soft winter wheat had the highest digestibility of any of the samples ground from this variety, namely, 92.8 per cent of the protein and 98 per cent of the carbohydrates, while 94.2 per cent of the energy was available to the body. Of the protein of bread from the entire-wheat flour milled from the same lot of wheat, 85.7 per cent, and of the carbohydrates 92.9 per cent were digestible, 88 per cent of the energy being available to the body. The lowest coefficients of digestibility were found in the graham bread, the values being 79.4 per cent for the protein, 89.3 per cent for the carbohydrates, and 82.6 per cent for the energy available to the body. As will be seen, there was a difference of 13.4 per cent in the average digestibility of the protein of the graham bread and white bread made of flour from the same lot of wheat, while 8.7 per cent less of the carbohydrates of the graham bread was digestible, and 11.6 per cent less of the energy was available. As in the case of the entire ration, differences attributable to individuality are noticeable, which are, however, not great enough to invalidate the general deduction that white bread is the most digestible, graham bread the least, and entire-wheat bread intermediate between them.

Table 35 gives a summary of the experiments on the basis of the proportion of total and digestible nutrients and available energy in the different grades of flour as milled from soft winter wheat:

Table 35.—*Proportion of total and digestible nutrients and available energy in different grades of soft winter-wheat flour as milled.*

Number of sample.	Grade of flour.	Protein.		Carbohydrates.		Heat of combustion per gram.	
		Total.	Digestible.	Total.	Digestible.	Total.	Available.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*	*Calories.*
221	Mixed-grade flour	12.30	10.93	75.94	72.90	4.010	3.645
219	Entire-wheat flour	12.80	10.82	74.40	66.66	4.020	3.384
240	Straight white flour	10.92	10.13	77.15	75.61	3.799	3.579
241	Entire-wheat flour	12.01	10.29	74.17	68.80	3.860	3.399
242	Graham flour	12.24	9.72	73.27	65.43	3.906	3.226

The digestible nutrients were obtained by multiplying the percentage of the total nutrients by the average digestion coefficients given in Table 34. The mixed-grade flour, for example, contained 12.3 per cent total protein, which was found to be 88.9 per cent digestible, being therefore equivalent to 10.93 per cent of digestible protein. The mixed-grade flour prepared from the Indiana wheat contained 10.93 per cent digestible protein, 72.90 per cent digestible carbohydrates, and 1 gram of the flour yielded 3.645 calories of available energy. The entire-wheat flour prepared from the same wheat yielded 10.82 per cent digestible protein, 66.87 per cent digestible carbohydrates, and 3.375 available calories per gram. The difference in digestible protein is small, being 0.11 per cent in favor of the mixed-grade flour. The difference in the digestible carbohydrates is quite large, being 6.24 per cent in favor of the mixed-grade flour. The difference in the available energy is also large, amounting to 0.261 calorie per gram in favor of the white flour.

While there is no material difference as to the amount of digestible protein in the two kinds of flour, the differences in digestible carbohydrates and available energy are decidedly in favor of the mixed-grade flour. The entire-wheat flour contained a larger amount of protein, but, as shown in Table 34, this protein is less digestible than that of the mixed-grade flour, which was more finely granulated.

The straight-grade flour prepared from the Michigan wheat contained 10.13 per cent digestible protein, 75.61 per cent digestible carbohydrates, and 3.574 calories of available energy per gram. Compared with graham flour, this shows 0.4 per cent of digestible protein, 10.18 per cent of digestible carbohydrates, and 0.353 calorie of available energy per gram in favor of the white flour. Compared with the entire-wheat flour, the results show a difference of 6.81 per cent digestible carbohydrates and 0.180 available energy per gram in favor of the straight-grade flour; the difference in digestible protein, though too small to be of significance, is 0.16 per cent in favor of the entire-wheat flour. In the description of the samples it was stated that the straight-grade flour did not contain all of the granular middlings which are usually included in the preparation of ordinary straight flours. Had the flour contained the granular middlings, the percentage of protein, it seems fair to conclude, would have been higher than 10.92. While the difference in total protein is 1.1 per cent in favor of the entire-wheat flour, the higher degree of digestibility of this constituent in the straight-grade flour makes the figures for the total digestible protein in the two kinds of flour practically the same. Hence, what is gained from the somewhat larger amount of protein in the entire-wheat and graham flours is lost in digestibility. While the difference between the digestible protein in the straight-grade and entire-wheat flours prepared from the same lot of soft wheat is small, the difference in digestible carbohydrates is large, being 6.8 per cent in favor of the white flour. Since a larger amount of digestible carbohydrates and available energy is secured from the mixed and straight-grade flours than from the entire-wheat flour and no appreciable differences were observed as to digestible protein, it would appear that a larger total amount of nutrients and energy is available to the body from the straight than from the entire-wheat or graham flours, a conclusion in accord with the results of all our former work.

That the lower degree of digestibility of the entire-wheat and graham flours was probably due at least in part to a coarser granulation of the particles, which consequently exposed a relatively smaller amount of surface to the action of the digestive fluids, was shown by a microscopical examination of the feces. The feces from both the entire-wheat and the graham flours under the microscope showed a larger proportion of starch particles that had not been acted upon in the digestive tract than the feces from standard patent flour. The micro-photographs reproduced (Pls. I–III) show the fineness of division of the three sorts of flour and the starch granules in the feces obtained from the standard patent, the entire-wheat, and the graham flours, prepared by grinding in a mortar.

These deductions are in accord with the results of numerous microscopical studies of the feces from different sorts of wheat products, and in this connection it is interesting to refer to some of these and closely related investigations. Among others may be mentioned the work of Rubner,[a] Pappenheim,[b] Constantinidi,[c] and Raudnitz.[d]

In general it may be said that these investigators found that starch was very thoroughly digested, but that the cells making up the outer portion of the wheat berry were little attacked by the digestive juices, and hence the contents of such cells were not assimilated. Rubner pointed out that the amount of undigested nitrogen increased with an increase in the amount of the outer portion of the grain retained in flour in milling. Rathay[e] reports experimental studies, of which he himself was the subject, in which the diet for a week consisted of graham bread and tea. The bread was made without leaven or yeast. The feces from the fifth and seventh day were examined microscopically. He found that the grain portions which had been little masticated were softened, but almost entirely undigested. From only a few of the outer cells of the endosperm had the starch grains and the proteid materials disappeared, while the greater part of these nutrients was excreted unchanged. The general conclusion from his investigations was that the greater portion of the feces consisted of undigested residues of wheat bran in the form of large flakes composed of the seed coats and aleurone layer. The latter leaves the intestines unchanged, probably because the thick walls of the aleurone cells prevent the action of digestive juices upon the cell contents. So far as can be learned, this investigation was the first which at all satisfac-

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[a] Ztschr. Biol., 15 (1879), p. 115.

[b] Lehrbuch der Müllerei (1890), 3d ed., cited by Moeller.

[c] Ztschr. Biol., 23 (1887), p. 447.

[d] Prag. med. Wchnschr., 7 (1892), pp. 1, 13.

[e] Jahresber. K. K. Realschule Sechshaus, Wien, 1874, cited by Moeller.

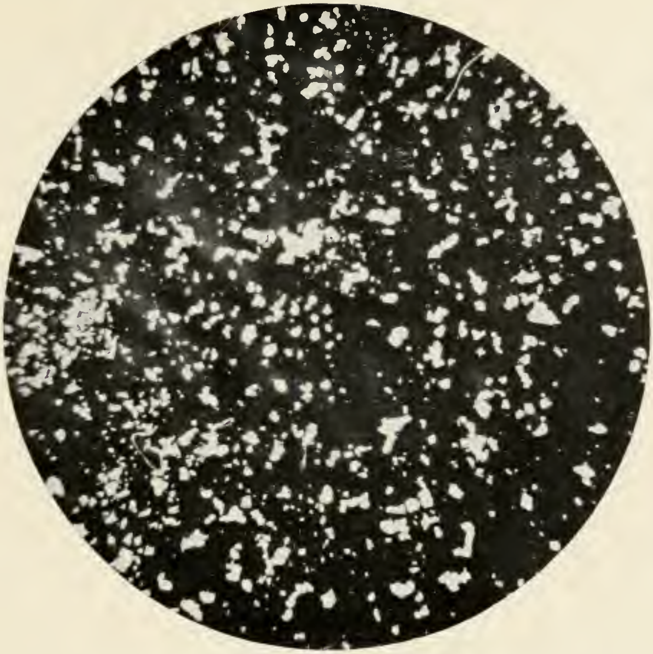

FIG. 1.—FLOUR PARTICLES FROM STRAIGHT PATENT FLOUR NO. 240 (MAGNIFIED 15 DIAMETERS).

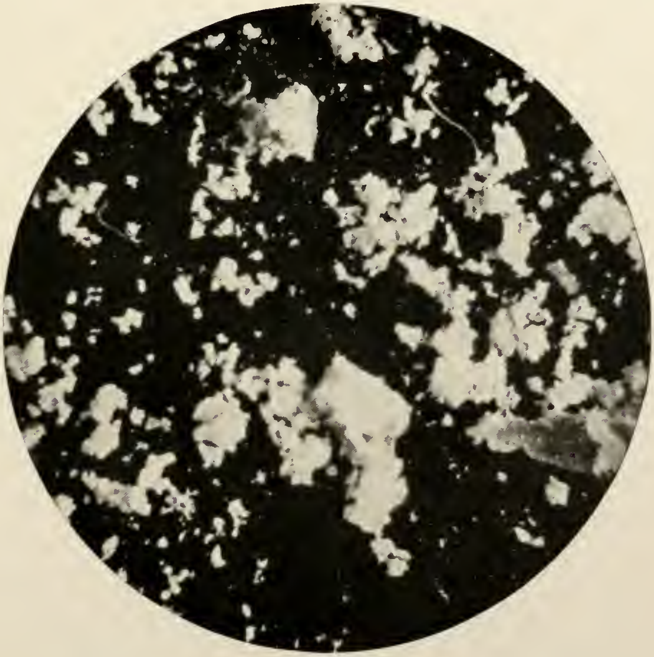

FIG. 2.—FLOUR PARTICLES FROM ENTIRE-WHEAT FLOUR NO. 241 (MAGNIFIED 15 DIAMETERS).

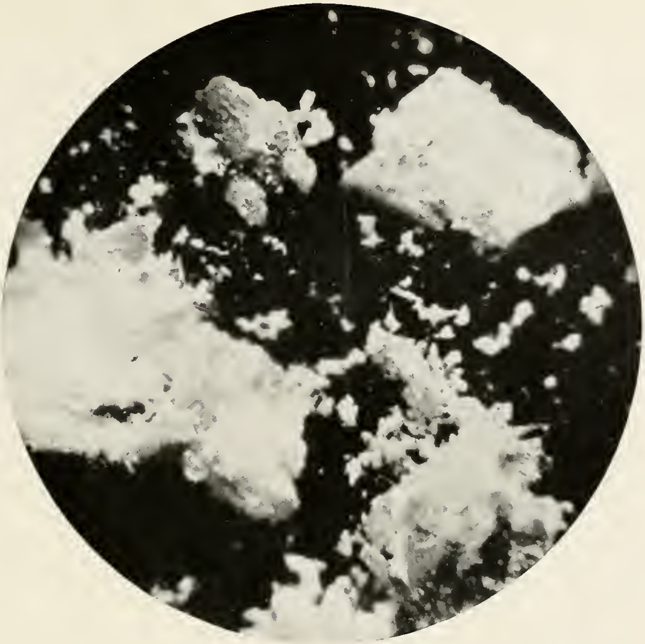

FIG. 1.—FLOUR PARTICLES FROM GRAHAM FLOUR NO. 243 (MAGNIFIED 15 DIAMETERS).

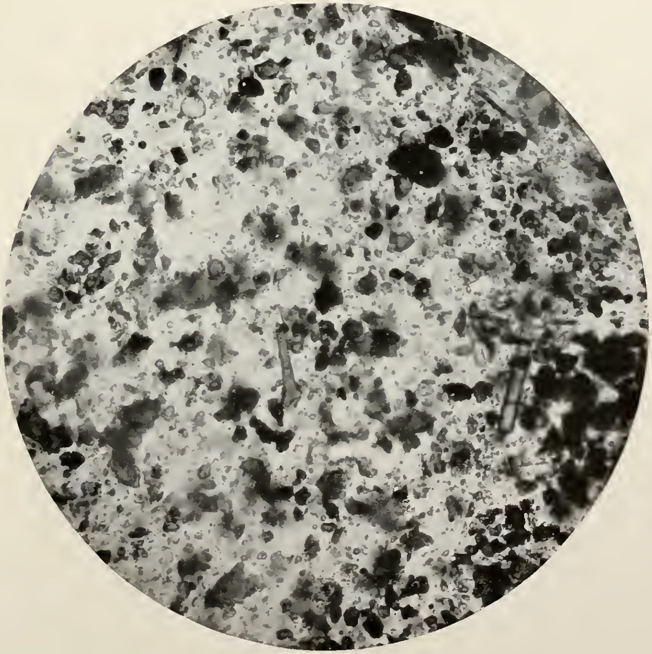

FIG. 2.—FECES FROM BREAD MADE FROM STRAIGHT PATENT FLOUR (MAGNIFIED 15 DIAMETERS).

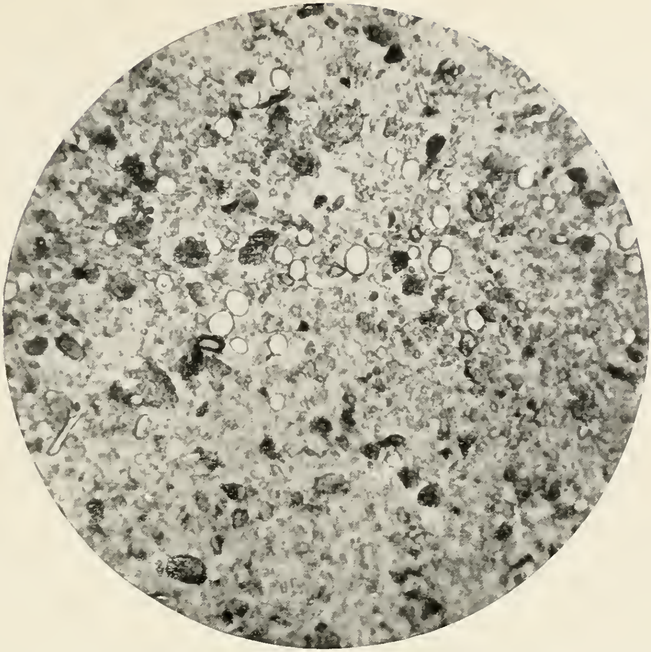

FIG. 1.—FECES FROM BREAD MADE FROM GRAHAM FLOUR (MAGNIFIED 15 DIAMETERS).

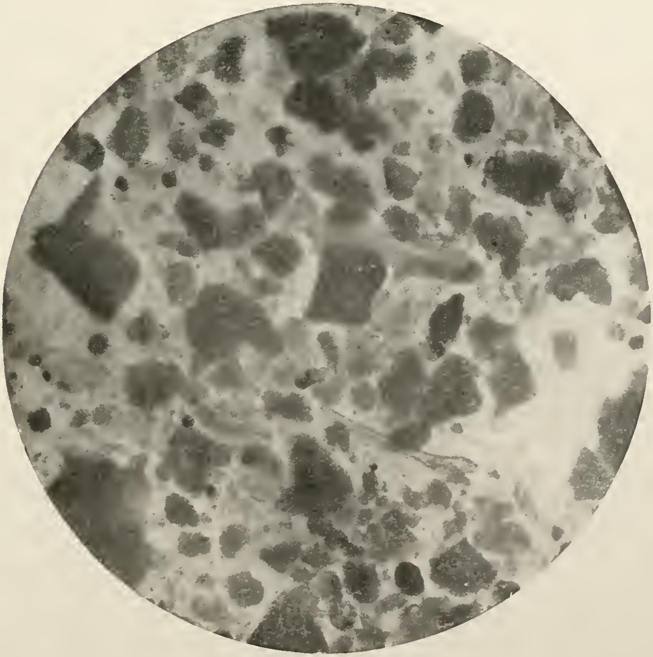

FIG. 2.—FECES FROM BREAD MADE FROM ENTIRE-WHEAT FLOUR (MAGNIFIED 15 DIAMETERS).

torily opposed Liebig's idea of the high value of the gluten layer of wheat.

Perhaps the most extended study of vegetable residues occurring in feces was made by Moeller[a]. In some of the experiments the diet consisted of coarse bread with butter and cheese; white bread, rice, and butter; bread, and porridge made of wheat grits and milk; bread, and porridge made from milk and flour; oat preparations, namely, oat grits, oat flake, soup, and oat cocoa; rye bread and various mixed diets, or diets in which potatoes or legumes predominated. Portions of feces were repeatedly washed with water and then examined under the microscope. The conclusion was reached that healthy individuals digested the starch of cereals and potatoes almost completely, even when the starchy foods were not in favorable mechanical condition, as is the case in bran from cereals, in rice, or in sliced potatoes; and further, that the soft cell walls of the starch cells are also digested. The aleurone layer of cereals in which the cell membranes consist of pure cellulose was not digested, nor were the protein and fat which form the contents of the cells digested unless the cell walls had been mechanically ruptured. The cells making up the germ were not digested or ruptured by the action of the digestive juices. The author believes that these experiments warrant the conclusion that fine flour is preferable to coarse flour. Comparative experiments with coarse flour and the same flour after passing through the intestinal tract, lead the author to the conclusion that the cell walls almost absolutely shield the cell contents of the aleurone layer from the action of the digestive juices, and he concludes that cereal brans should be regarded as indigestible. The outer layer of the cereal grains, including endosperm cells with their starch content, was also found to be undigested.

Laboratory experiments indicated that cellulose which had not lignified was little attacked by digestive juices, the amount being inversely proportional to the thickness of the cell membrane. On the other hand, the middle lamellæ were readily disintegrated by digestive juices. Tests with laboratory reagents also showed that the inner side of the gluten cells was most resistant but after a time softened, and this indicates that possibly gluten cells may become softened in the intestine and then digested. That this occurs very seldom is indicated by the large number of unchanged cells found in the feces.

As noted above, in connection with the experiments reported in this bulletin, a microscopical examination of the feces showed that in those from the graham and entire-wheat breads made from flour ground from the same lot of soft wheat, a much larger number of unaltered starch granules were present, and the particles had not been as completely acted upon by the digestive fluids as in the case of the straight-grade-flour bread.

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[a] Ztschr. Biol., 35 (1897), p. 291.

Summarizing briefly the results of the fifteen experiments with soft-wheat flours, it appears that while the graham and entire-wheat flours contain a larger amount of protein and energy, the lower degree of digestibility of these flours, due to the coarser granulation, renders available to the body a smaller proportion of total nutrients as well as energy than in the case of straight-grade flours, ground from the same wheat, which are more finely granulated and more completely digested. This is entirely in accord with the results obtained in the investigations with hard-wheat flours more exhaustively milled.

As was the case in the tests with bread from different grades of hard-wheat flour, no variations were observed in the metabolism of nitrogen which could be attributed to the use of the different sorts of flour constituting the principal part of the diet.

GENERAL SUMMARY OF RESULTS AND CONCLUSIONS.

The experiments with hard wheat milling products reported in the present bulletin are the latest of a fairly extended series which has given uniform results. The experiments with soft wheat are the first of a proposed series and are less numerous than those made with hard wheat. The results already obtained, however, are in accord with what has been learned regarding the milling products of hard wheat. Some general deductions from the experiments as a whole seem warranted.

As shown by analysis the patent flour, ground from the hard and soft wheats studied, had a somewhat lower protein content than the graham flour and entire-wheat flour ground from the same wheats, but according to the results of digestion experiments with the different grades of flour from these wheats, the proportion of digestible protein and the available energy in the patent flour was larger than in the coarser grades. The lower digestibility of the protein in the latter is, it appears, due to the fact that in these grades a considerable portion of this constituent is contained in the coarser particles (bran) and thus escapes digestion as it is not acted upon by the digestive juices. Thus, while there may be actually more protein in a given amount of graham or entire-wheat flour than in an equal amount of patent flour ground from the same wheat, the body secures less of the protein and energy from the coarse flour than it does from the fine, since although the retention of the bran and germ increases the percentage of protein it decreases the digestibility. By digestibility is meant the difference between the amounts of the several nutrients consumed and the amounts excreted in the feces. No attempt was made to study the ease or rapidity of digestion of the different sorts of flour. When the digestibility of different grades of patent flour was studied it was found that there was no marked difference between standard patent flour and the other grades in this respect. The digestibility of all these flours was found to be high, apparently owing largely to their mechanical condition, that is, owing to the fact that they were finely ground.

Microscopical studies of the feces from bread made from the different grades of flour indicate that the superior digestibility of patent-flour bread is due to the fineness of division of the flour particles and also to the fact that the cell walls of the material making up the interior of the wheat berry are less resistant to digestive juices than the walls of the cells making up the outer layers of the grain. In other words, the patent flour is superior as regards digestibility, on account of both its mechanical condition and its physical properties.

In discussions of the comparative value of fine wheat flour and the coarser grades, it is often claimed that the larger proportion of mineral matter, and especially phosphorous compounds, in whole-wheat and graham flours is a reason for preferring them to patent flour. In this case also it is undoubtedly true that the proportion of mineral constituents which is digestible, or, in other words, which the body can retain, from the different sorts of flour, must be considered, as well as the amounts which chemical analysis shows to be present in the food. In view of the fact that there is apparently no satisfactory method for determining the proportion of ash in the feces, derived from metabolic products, and that it is, therefore, impossible by present methods to determine the true digestibility of the mineral constituents, no values for the digestibility of ash have been included in the present bulletin. It may be noted in this connection that it is a well-recognized fact that when the coarser milling products are fed to cattle no great amount of phosphorus (one of the most important manurial elements) is retained in the animal body. This may possibly be an indication that the phosphorus, even if present in considerable amounts in the feed, is not in a form which can be assimilated by animals. This is, however, little more than conjecture, and more experiments with man and the lower animals are needed before satisfactory conclusions can be drawn.

Briefly stated, the most important deductions from the results of these investigations with hard and soft wheat are in accord with the conclusions drawn from the earlier investigations of this series. The nutritive value of flour, in so far as the quantities of digestible protein, fats, and carbohydrates, and available energy are concerned, is not increased by milling the wheat in such a way as to retain a large proportion of bran and germ. The differences in the amounts of total nutrients furnished the body by the various grades of flour are, however, relatively small, all grades being quite thoroughly digested. The coarser flours have a tendency to increase peristaltic action, and are on this account especially valuable for some persons. Judged by composition and digestibility, all the flours are very nutritious foods, which experience has shown are wholesome as well. When also the fact is taken into account that they furnish nutritive material in an economical form, their importance is evident. The fact must not be lost sight of that using different grades of flour for bread making and other household purposes offers a convenient method of adding to the variety of the daily diet, a matter which is of undoubted importance.

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Bul. 93. Sugar as Food. By Mary H. Abel. Pp. 27.
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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 127.

A. C. TRUE, Director.

INSTRUCTION IN AGRONOMY AT SOME AGRICULTURAL COLLEGES.

BY

A. C. TRUE and D. J. CROSBY.

1862 1889

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., May 18, 1903.

Sir: I have the honor to transmit herewith a report on courses in agronomy in several agricultural colleges. There is now considerable activity in our agricultural colleges in developing and strengthening the courses of instruction in this division of the science of agriculture. The report has been prepared at the suggestion of the committee on methods of teaching agriculture of the Association of American Agricultural Colleges and Experiment Stations, and is an outcome of the work of that committee. I feel sure that such a comparative presentation of courses actually being given in some of our colleges will aid in the further development and strengthening of this line of work in other institutions, and I therefore recommend the publication of the report as Bulletin 127 of this Office.

The illustrations have been carefully selected from a large number furnished by the colleges, and are intended to show distinctive features of the equipment for instruction in agronomy at the institutions represented in the bulletin.

Respectfully, A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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INSTRUCTION IN AGRONOMY AT SOME AGRICULTURAL COLLEGES.

PURPOSE AND SCOPE OF THIS BULLETIN.

This bulletin is based on the reports of the committee on methods of teaching agriculture of the Association of American Agricultural Colleges and Experiment Stations and on further inquiries made by the Office of Experiment Stations. It is intended to supplement the work of the committee in collating detailed information regarding instruction in agronomy. The status of that work at the time the committee made its sixth report[a] is indicated by the following paragraph from that report:

> After consultation with the instructors in agriculture in the different colleges, it has seemed well for your committee to undertake to present in some detail information regarding the courses in agriculture and the facilities for instruction in this subject in our colleges. It is especially desirable to put on record data regarding distinctive features of these courses and the materials for demonstration and illustration already existing in different institutions. Your committee has, therefore, undertaken during the present year to collate such information regarding the course in agronomy. Considerable material has already been accumulated, but some time must elapse before it will be in form for publication. Your committee therefore asks that it may be granted leave to print its report on agronomy in our agricultural colleges, in whole or in part, in the next proceedings of this association, and be given authority to negotiate with the Office of Experiment Stations for the separate publication of its detailed report on this subject.

Authority to publish its detailed report in accordance with the above request was granted the committee, which, however, was not able to prepare the material in time for printing in the proceedings of the association. This Office undertook, therefore, to complete the report and publish it.

Subsequent inquiries on the part of the Office of Experiment Stations by correspondence, by members of the Office force making visits of inspection to the agricultural experiment stations, and by a special officer sent to visit a number of the colleges, showed that while many of the agricultural colleges have made some progress in differentiating agronomy from the other subdivisions of agriculture, only a few have developed well-balanced courses in agronomy, with laboratory and field practicums in which special forms for scoring different crops and specially devised apparatus are used. It soon became apparent that it would not be feasible to publish within the scope of a Department bulletin detailed information regarding the courses of study in all the agricultural colleges in the United States and, furthermore, that such publication would not at present be desirable because (1) it would include a number of institutions that have not yet been able or have not found it desirable to differentiate agronomy from the general subject of agriculture; and (2) it would include some colleges that are just reorganizing their courses of instruction with reference to the subdivisions of agriculture, including agronomy, and are not now in a position to make a showing commensurate with their facilities for instruction.

---

[a] Presented at the convention of the Association of American Agricultural Colleges and Experiment Stations in Washington, D. C., November 12-14, 1901.

It has been decided, therefore, to include in this bulletin (1) a brief review of the work of the committee on methods of teaching agriculture, together with such excerpts from the reports of that committee as have a bearing on the present discussion; and (2) detailed descriptions of courses in agronomy in seven agricultural colleges—six in the United States and one in Europe. The institutions selected include (1) two colleges not connected with universities—Alabama in the South and Michigan in the North; (2) two university colleges having schools of agriculture (agricultural high schools) connected with them—Minnesota and Nebraska; (3) two university colleges in which no provision for preparatory work is made—Illinois and Ohio; and (4) a university college in Germany—the Agricultural Institute of the University of Göttingen.

In the detailed statements regarding the course in agronomy in these institutions the four-year agricultural course has been considered in a general way as to its purpose, requirements for admission, and scope; then attention has been given to agronomy, its position in the four-year course, preparation for it secured by means of previous work in botany and chemistry, its scope and the method of presentation to the students. Under this last head an account has been given of the equipment used, such as buildings, lecture and laboratory rooms, apparatus, collections, special forms, library facilities, and land, and the leading features of this equipment have been illustrated. In the preparation of these detailed statements Prof. J. F. Duggar, of Alabama; Dr. C. G. Hopkins, of Illinois; Prof. J. A. Jeffrey, of Michigan; Prof. W. M. Hays, of Minnesota; Prof. T. L. Lyon, of Nebraska, and Prof. W. D. Gibbs, of Texas (formerly of Ohio), have rendered valuable assistance.

WORK OF THE COMMITTEE ON METHODS OF TEACHING AGRICULTURE.

The first report of the committee on methods of teaching agriculture[a] pointed out that "one great obstacle to the intelligent discussion of the scheme of agricultural instruction and the methods of agricultural teaching is the lack of a definite nomenclature of the subject," and suggested "for the consideration of the association a tentative scheme for the division of what is commonly designated agriculture in courses of study into several distinct branches or subdivisions, and for giving each of these branches a definite name, as follows:

Agriculture	1. Agronomy, or agriculture (technical).	Climate, soils, fertilizers, and crops—plant production.
	2. Zootechny, or animal industry.	Animal physiology and animal production.
	3. Agrotechny, or agricultural technology.	Agricultural industries, e. g., dairying, sugar making.
	4. Rural engineering, farm mechanics, or farm equipment.	Roads, drains, irrigation systems, farm buildings, etc.
	5. Rural economy or farm management.	General policy of farm management, rural law, agricultural bookkeeping, etc.

In its second report[b] the committee first undertook "to determine the general relation of a course in technical agriculture to the other courses of study which should be connected with this to form a four-year course in an agricultural college," adopting as a working basis the following portion of the report of the committee on entrance requirements, courses of study, and degrees:[c]

> In the judgment of your committee, it is not too much to require the equivalent of fifteen hours per week of recitations and lectures, together with ten hours per week of laboratory work, or practicums, including the time devoted to military science and drill. Upon this basis the above-mentioned general studies should be assigned a relative importance, approximately as follows:

	Hours.
Algebra	75
Geometry	40
Trigonometry	40
Physics (class-room work)	75
Physics (laboratory work)	75
Chemistry (class-room work)	75
Chemistry (laboratory work)	75
English	200
Modern languages	340
Psychology	60
Ethics or logic	40
Political economy	60
General history	80
Constitutional law	50
Total	1,285

---

[a] Report presented to the Association of American Agricultural Colleges and Experiment Stations at the convention held in Washington, D. C., November 10–12, 1896. See U. S. Dept. Agr., Office of Experiment Stations Bul. 41, p. 57, and Circ. 32.

[b] See U. S. Dept. Agr., Office of Experiment Stations Bul. 49, p. 29, and Circ. 37.

[c] See U. S. Dept. Agr., Office of Experiment Stations Bul. 41, p. 52.

The total number of hours included in a four-year course, allowing fifteen hours per week for thirty-six weeks, would be 2,140; with ten hours' laboratory work, or practicums, added, 3,600. In general terms, therefore, the foregoing general studies should comprise about two-fifths of the work required for a bachelor's degree.

The committee on methods of teaching agriculture then suggested "additional subjects to be included in a four-year course in agriculture leading to the degree bachelor of science," as follows:

	Hours.
Agriculture	486
Horticulture and forestry	180
Veterinary science, including anatomy	180
Agricultural chemistry, in addition to general requirement	180
Botany (including vegetable physiology and pathology)	180
Zoology (including entomology)	120
Physiology	180
Geology	120
Meteorology	60
Drawing	60
Total	1,746

Taking up, then, the subject of agriculture, the committee recommended the following allotments of time to its subdivisions:

	Hours.
1. Agronomy, or plant production	132
2. Zootechny, or animal industry	162
3. Agrotechny, or agricultural technology	72
4. Rural engineering, or farm mechanics	60
5. Rural economics, or farm management	60
Total	486

It was also announced that the committee would next take up in detail the topics properly included under the head of "Agronomy," "with a view to presenting a syllabus of a course in that subject which shall show with some fullness the topics to be treated, their relative importance, the time which should be devoted to each, and especially the order of presentation which conforms most closely to sound pedagogical principles." This was done in the third report[a] of the committee, which was divided into three parts, as follows:

(1) A syllabus defining the limits of a course in agronomy, and stating the topics included in agronomy in the order in which they should be presented to students, i. e., in their logical and pedagogical order.

(2) A series of lecture or chapter headings showing how the syllabus for agronomy may be applied in preparing a course of lectures or a text-book on this subject, covering ninety-nine class-room hours or periods of sixty minutes each, i. e., three lecture or recitation periods a week.

(3) A series of subjects for practicums or laboratory exercises to be used in connection with the class-room work in agronomy, and covering the thirty-three remaining hours or periods (equivalent to sixty-six hours of sixty minutes each), assigned to the course in agronomy, i. e., one practicum per week.

---

[a] See U. S. Dept. Agr., Office of Experiment Stations Bul. 65, p. 79, and Circ. 39.

It has been the object of the committee to make such an outline of this course as can easily be adjusted to the requirements of institutions with different organization and environment. While the syllabus is intended to limit the range of subjects which may properly be included under agronomy, the amount of attention which shall be given to particular topics will vary according to circumstances. The series of chapters and practicums are in a measure intended simply to show a way in which the subject of agronomy may be presented in actual practice. This is especially true of that portion of the course which relates to individual farm crops, to which attention will naturally be given according to their relative importance in different localities

SYLLABUS OF COURSE IN AGRONOMY.

Definition	Theory and practice of the production of farm crops. In agronomy we need to consider the several kinds of plants grown as farm crops under the following subjects:
The plant	Structure (anatomy). Composition. Physiology. Environment.
Plant production	In agriculture has for its object the adaptation of environment to the anatomy and physiology of the plants under cultivation, with a view to securing crops which are best suited to the uses of man or the domestic animals.

We may conveniently begin the study of plant production by considering the general characteristics of the environment of plants as grown in the field.

Environment (General factors.)	Light.		
	Heat.		
	Moisture		Plant food.
	Air		
	Soil	Natural	
		With fertilizers	

But environment may be conveniently divided according to position, as follows:

Environment (Divided according to position.) (Chapters I-III of lecture outline page 16.)	1. Above ground (climate)	Light	Study the relation of each of these factors to plant growth, and also briefly their effects in different combinations, i. e., different climates.
		Heat	
		Moisture	
		Air	
	2. Under ground (soil)	Heat	Point out that the relation of these factors to plant growth may be most clearly perceived by first considering them in their relation to each other
		Moisture	
		Air	
		Earth (soil)	
		Fertilizers	

Soil (Chapters IV-XXXI.)

- Definition—Nature.
- Functions.
- Origin
  - Brief geological outline.
  - Weathering of rocks.
  - Accumulation of organic matter.
  - Transformation of organic matter (nitrification and denitrification, etc.).
  - Additions from atmosphere.
- Properties
  - Chemical.
  - Physical
    - Weight
    - Color
    - Texture
    - Capillarity
    - Permeability
    - Absorptive power.
    - Classification of soils, on the basis of their properties.
- Temperature.
- Air.
- Moisture
  - Sources
  - Amounts
    - Water table.
    - Hygroscopic moisture.
    - Rainfall.
    - Irrigation—Methods.
  - Drainage
    - Purpose and effects.
    - Methods.
  - Conservation
    - Purpose.
    - Methods.
- Tillage
  - Purpose and effects.
    - Chemical.
    - Physical.
    - Biological.
  - Methods.
- Fertilizers
  - Definition.
  - Methods and effects of action.
    - Chemical.
    - Physical.
    - Biological.
  - Classification.
    - 1. According to constituents—
      - *a.* Nitrogenous.
      - *b.* Phosphoric.
      - *c.* Potassic.
      - *d.* Other amendments.
    - 2. According to form—
      - Farm manures.
        - *a.* Green manures.
        - *b.* Animal manures.
      - *c.* Commercial—classify principal forms.
  - (Study first the general theory of fertilizers according to above scheme and then consider in as much detail as may be deemed desirable different kinds of fertilizers, using Schedule A.)

Schedule A.

- SOIL—Continued (Chapters IV-XXXI.)
  - Fertilizers
    - Kinds of fertilizers.
      - Name.
      - Description.
      - Properties
        - Chemical—composition.
        - Physical.
      - Place in classifications.
      - Sources.
      - Uses.
      - Preparation, care, and handling.
      - Application.
      - Effects
        - Chemical.
        - Physical.
        - Biological.
      - Economy
        - Extent of production.
        - Pecuniary value.
  - Waste and renovation.
    - Washing.
    - Transportation by wind and water.
    - Leaching.
    - Oxidation.
    - Cropping—Rotation of crops, systems of farming.

Having considered in a general way the theory and practice of plant production as related to the structure, physiology, and environment of the plants grown as farm crops, we come next to consider the production of different kinds of crops more in detail.

- FARM CROPS (Chapters XXXII-XXXIII.)
  - Classification (The classification and the kinds of plants to be named under each class will vary according to circumstances.)
    - Cereals—Wheat, oats.
    - Grasses—Timothy, brome grass.
    - Legumes—Red clover, alfalfa.
    - Tubers—Potatoes.
    - Roots—Mangels.
    - Sugar plants—Sugar cane, sugar beets.
    - Fibers—Cotton, flax, hemp.
    - Stimulants—Tobacco, tea, coffee.
    - Medicinal and aromatic plants—Ginseng, mint.
    - Miscellaneous—Canaigre, peanuts.
  - Methods of improvement.
    - Breeding.
    - Selection.

Next study individual farm crops according to the following scheme:

INDIVIDUAL FARM CROPS. (Chapters XXXIV–LXI.) (The crops to be studied will vary according to locality and other circumstances.)

- Name.
- Place in classification.
- Structure.
- Composition.
- Physiology.
- Botanical relations.
- Varieties
  - Classification.
  - Improvement.
- Geographical distribution.
- Culture
  - Choice and preparation of soil.
  - Manuring.
  - Seeds (or other parts of plants used for planting)—Selection—amount—treatment.
  - Planting.
  - Cultivating.
  - Place in rotation.
- Harvesting.
- Preservation.
- Uses.
- Preparation for use.
- Obstructions to growth, preservation, or use.
  - Weeds
  - Fungi
  - Bacteria
  - Insects
  - Birds
  - Quadrupeds
    - Means of repression.
- Production.
- Marketing.
- History.

OUTLINE FOR A COURSE OF LECTURES OR A TEXT-BOOK ON AGRONOMY.

[The lectures are intended to cover 99 hours.]

Chapter I. General climatic conditions.
II. Plant food and growth.
III. Air as a source of plant food.
IV. The nature, functions, origin, and wasting of soils.
V. Properties of soils, chemical and physical. Classifications, texture, composition, and kinds of soils.
VI. Physics of soils as related to plant growth (capillarity, solution, diffusion, and osmosis).
VII. Soil temperature.
VIII. Relation of air to soil.
IX. Soil water.
X. Irrigation.
XI. Improvement of soil through drainage.
XII. Drainage methods.
XIII. Conservation of soil moisture.
XIV. Physical effects of tillage.
XV. Chemical and biological effects of tillage.

Chapter XVI. Methods of tillage.
XVII. Methods of tillage.
XVIII. Fertilizers—Methods and effects of action.
XIX. Fertilizers—Classification by constituents and form.
XX. Sources and uses of nitrogen.
XXI. Sources and uses of phosphoric acid.
XXII. Sources and uses of potash.
XXIII. Sources and uses of other amendments.
XXIV. Practical advice on the use of commercial fertilizers.
XXV. Humus and green manuring.
XXVI. Animal manures. General statements.
XXVII. Manures produced from various animals.
XXVIII. Care, preservation, and application of manure.
XXIX. Waste and renovation of soils.
XXX. Rotation of crops—General statements.
XXXI. Rotation of crops—Systems of farming.
XXXII. Farm crops—Classification, production; reasons for choice.
XXXIII. Improvement of farm crops.
XXXIV. Wheat—Structure, composition, and varieties.
XXXV. Wheat—Culture, harvesting, and preservation.
XXXVI. Wheat—Obstructions to growth, preservation, and use.
XXXVII. Wheat—Production, marketing, history.
XXXVIII. Corn.
XXXIX. Corn.
XL. Corn.
XLI. Corn.
XLII. Rice.
XLIII. Oats.
XLIV. Barley and rye.
XLV. Grasses.
XLVI. Grasses.
XLVII. Clovers.
XLVIII. Pastures.
XLIX. Silage.
L. Forage crops.
LI. Potatoes.
LII. Potatoes.
LIII. Root crops—Mangels, beets, turnips.
LIV. Sugar plants—Sugar beets.
LV. Sugar plants—Cane, sorghum, etc.
LVI. Fiber plants—Cotton.
LVII. Fiber plants—Cotton.
LVIII. Fiber plants—Flax, hemp, jute, ramie, sisal, etc.
LIX. Stimulants—Tobacco, tea, coffee.
LX. Medicinal and aromatic plants.
LXI. Miscellaneous plants—Buckwheat, broom corn, peanuts, hops, canaigre, etc.

[The order of discussion of the different crops will be the same as in the case of wheat. The details to be given for each crop will vary with the importance of the crop in any region.]

PRACTICUMS OR LABORATORY WORK IN AGRONOMY.

[The practicums are intended to cover 33 laboratory periods, i. e., 66 hours.]

1. Determination of specific gravity of soils.
2. Determination of volume weight of soils.
3. The power of retaining moisture in the soil in its highest degree of looseness.
4. The power of retaining moisture in the soil when compacted.
5. Rate of percolation of water through soils.
6. Rate of percolation of air through soils.
7. Effect of mulches upon evaporation of water from soils.
8. Behavior of soils toward gases.
9. Capillary attraction in soils.
10. Determination of cohesion in soils.
11. Mechanical analysis of soils.
12. Mechanical analysis of soils.
13. Study of root systems of principal crops.
14. Study of root systems of principal crops.
15. Study of root systems of principal crops.
16. Study of varieties of corn in field.
17. Scoring ears of corn.
18. Study of effect of fertilizers on one or more crops in fall.
19. Study of effect of fertilizers on one or more crops in early spring.
20. Study of effect of fertilizers on one or more crops near harvest.
21. Study of varieties of wheat in sheaf and by sample.
22. Study of varieties of wheat in sheaf and by sample.
23. Study of varieties of wheat in field.
24. Study of varieties of oats or other grain in sheaf and by sample.
25. Study of varieties of oats or other grain in field.
26. Study of varieties of potatoes by sample.
27. Study of varieties of potatoes in field.
28. Study of varieties of grasses and forage crops in field in fall.
29. Study of varieties of grasses and forage crops in field in early spring.
30. Study of varieties of grasses and forage crops near harvest in field.
31. Study of varieties of grasses and forage crops by sample and preparation of abstracts of station experiments on climatic and soil conditions and upon quality and yield.
32. Study of varieties of grasses and forage crops by sample and preparation of abstracts of station experiments on climatic and soil conditions and upon quality and yield.
33. Study of varieties of grasses and forage crops by sample and preparation of abstracts of station experiments on climatic and soil conditions and upon quality and yield.

DETAILED DESCRIPTION OF COURSES IN AGRONOMY.

ALABAMA POLYTECHNIC INSTITUTE.

In the Alabama Polytechnic Institute five four-year courses lead to the degree of bachelor of science. These courses are chemistry and agriculture, civil engineering, electrical and mechanical engineering, general course, and pharmacy. Elementary agriculture (breeds of live stock) is taught in the third term of the freshman year in all courses. Agriculture is an elective throughout the sophomore year of the course in civil engineering, and is required throughout the sophomore and junior years of the course in chemistry and agriculture. This last course, then, may be considered the agricultural course of the Polytechnic Institute. The student in this course devotes about one-fifth of his time to English, history, and economics; about two-fifths to pure science and two-fifths to applied sciences and technical training.

Admission to the four-year courses is by examination or by certificate from schools having approved courses of study. Applicants for admission must be at least 15 years of age, and, if admitted by examination, must be qualified to pass satisfactory examinations in (1) geography and history of the United States; (2) English, including grammar, composition, reading, and English classics; and (3) mathematics, including arithmetic and algebra through quadratic equations. "Those applicants who desire to continue the study of Latin should be qualified to pass a satisfactory examination in Latin grammar and the first two books of Cæsar in addition to the above subjects."

The course in agronomy is given during the second and third terms of the sophomore years. It is preceded by a two-hour course in animal husbandry during the third term of the freshman year, a two-hour course in dairying during the first term of the sophomore year, and a three-hour course of lectures and one laboratory exercise per week in general chemistry during the first term of the sophomore year, and is followed by courses in systematic and structural botany (lectures and laboratory), plant physiology, and agricultural chemistry.

The course in agricultural chemistry is given in the senior year and "consists of lectures on chemistry in its application to agriculture (two per week, during second and third terms), and includes a thorough discussion of the origin, composition, and classification of soils, the composition and growth of plants, the sources of plant food and how obtained, the improvement of soils, the manufacture and use of fertilizers, the chemical principles involved in the rotation of crops, the feeding of live stock, and the various operations carried on by the intelligent and successful agriculturist." During the same periods the students do laboratory work in quantitative analysis six hours per week. The principal reference books used in agricultural chemistry are Johnson's How Crops Grow and How Crops Feed, Lupton's Elementary Principles of Scientific Agriculture, Johnson and Cameron's Elements of Agricultural Chemistry, Storer's Agriculture, scientific journals, reports of the United States Department of Agriculture, and the bulletins and reports of the various domestic and foreign agricultural departments and stations. "The laboratories, which are open from 9 a. m. to 5 p. m. during six days in the week, are amply supplied with everything necessary for instruction in chemical manipulation."

Instruction in agronomy is given by the professor of agriculture. "In the second term of the sophomore year the following subjects are studied: Soils—chemical and physical properties, defects, and means of improvement; the control of water, including means of conserving moisture in times of drought; terracing, underdrainage, and open and hillside ditches; objects and methods of cultivation; agricultural implements; rotation of crops; and improvement of plants by crossing, selection, and culture. The third term of the sophomore year is devoted to the staple crops produced in Alabama, to forage plants adapted to the South, and to plants valuable for the renovation of soils. The more important crops are treated with reference to varieties, soil and fertilizer requirements, methods of planting and cultivating, and uses." In all classes there are mid-term examinations and term-end examinations.

Two hours per week are devoted to lectures, in which the number of students ranges from 10 to 25, and two afternoons per week are given up to farm practice, during which time the classes are divided into sections of from 6 to 9 students. A part of the field work is conducted by the professor of agriculture and a part is in charge of an assistant in agriculture.

In every class the student is encouraged to independent thought on agricultural problems rather than to depend on "rules of thumb," so that he may be prepared to adapt his practice in after years to changed conditions of soil, climate, capital, market, etc. An effort is made to keep before the student the difference between the widely applicable principles on which every rational system of farming rests and the details that vary with changing conditions. The conditions of soil, climate, etc., prevailing in different parts of Alabama are kept constantly in view. As far as limited time allows, attention is directed to agricultural literature now accumulating so rapidly in this and in foreign countries, to the end that in future years the student may know where and how to seek the information that he may need.

Among the reference books and other literature used by students in agronomy are Soils and Crops of the Farm, Morrow and Hunt; Forage Plants, Shaw; The Fertility of the Soil, Roberts; Corn Culture, Plumb; The Physics of Agriculture, King; other recent American works on agriculture; bulletins of the United States Department of Agriculture and of the experiment stations in the different States, and a number of farm journals.

Lectures in agronomy are given in the main building in a class room provided with chairs and arm rests for 60 students, two sides of the room being occupied by cases for specimens. Three small barns and a gin room serve partly as laboratories for students when engaged in indoor work. Plats on the experiment-station farm showing the effect of fertilizers, methods of culture, etc., and collections of varieties are used as object lessons for students.

The following exhibits will give an idea of the nature and scope of the examinations required in agronomy and of the notes taken by students in the field:

Exhibit No. 1.

EXAMINATIONS IN AGRONOMY.

Examination in beginning agronomy, second term, sophomore year.

I. (*a*) In what kind of weather and at what time of year can wetter soils be safely plowed than under other conditions? Explain. (*b*) Does a clay or a sandy soil contain more moisture when plants begin to wilt? Explain.

II. (*a*) Discuss the importance or nonimportance of the hygroscopic power of soils. (*b*) Discuss the practicability or otherwise of determining what fertilizers to apply by an analysis of the soil.

III. Discuss capillarity in the soil (direction of movement, favorable conditions, effect of slight rain after long drought, etc.).

IV. Explain fully the effect of cultivation on the moisture in the different layers of soil.

V. Discuss fully the size and use of the roller and its effects on the soil, and state conditions when it should be used.

VI. Discuss the general direction for ditches, methods of making junctions, and draw cross section illustrating (*a*) carrying canal, (*b*) shallow hillside ditches, (*c*) open drainage ditch.

VII. (*a*) Discuss grades for open tile drains. (*b*) Make drawing of homemade level and show how used (*c*) in making a terrace and (*d*) in giving a uniform grade to bottom of a ditch.

VIII. Irrigation. (*a*) Give three commonest sources of water in order of cheapness. (*b*) What advantages in furrow system over flooding system? (*c*) What levels would head ditches follow and how would nature of soil influence the grade of the rows?

IX. Discuss fall versus spring plowing in the Gulf States.

X. (*a*) Give a three-year rotation for cotton farm, showing why the crops should follow in the order stated. (*b*) Outline a rotation that will put half the land in cotton each year. (*c*) Construct a five-year rotation for a mixed cotton and stock farm in the central prairie region of Alabama, stating when each crop is planted.

Examination in agronomy (forage plants), third term, sophomore year.

I. (*a*) What advantages has fall sowing of grasses and clovers over spring sowing? (*b*) Mention three legumes that can not be sown in fall and give best month for sowing each of the three.

II. (*a*) Compare early versus late cutting of hay. (*b*) When cut red clover?

III. Give means of distinguishing small grains of oats, wheat, barley, and rye.

IV. Discuss Texas blue grass.

V. Discuss redtop.

VI. Discuss white clover.

VII. Discuss culture and uses of rape plant.

VIII. Give time of sowing, amount of seed, soil requirements, and uses of melilotus.

IX. Velvet beans—uses and culture.

X. Hairy vetch—discuss best mixtures of this with other seed for given conditions.

Exhibit No. 2.

STUDENTS' FIELD NOTES.

Notes on varieties of corn.

Variety.	Number of ears and nubbins per 100 stalks.		Distance from ground to lower ear.						Average distance from ear to ground.		Percentage of ears below horizontal line.	Tipcovered by shuck, 5; tip exposed, 0.	Remarks.
	Ears.	*Nubbins.*	*Ft.*	*Ins.*	*Ft.*	*Ins.*	*Ft.*	*Ins.*	*Ft.*	*Ins.*			
Hickory King	48	42	2	9	3	2	3	2	2	9½	63	4	Stalks very small and very early.
			2	6	2	4	....						
			2	8	4	2	3	7					
			....		2	9	2	4					
Shaw	90	22	3	10	5	8	7	5	4	9	25	5	Medium light and late; ears above medium in length.
			3	6	4	4	5	0					
			4	2	5	9	....						
			5	10	3	6	....						
Arnolds	62	32	2	9	4	3	4	6	4	0	28	3.5	Late; medium ears.
			3	9	4	6	4	6					
			3	9	3	0	5	4					
			5	0	....		....						
Experiment Station Yellow.	100	36	3	3	3	5	3	8	3	3½	22	4	Above medium height; medium early.
			3	5	4	1	3	8					
			3	9	4	0	3	7					
			3	2	....		....						
Coeke	114	72	3	7	4	10	....		4	3	67	4.5	Small stalk, long, slender ears; early.
			4	2	3	8	....						
			4	6	4	0	....						
			5	0	1	0	....						
			3	0	3	8	....						
Mosby	124	36	4	4	4	3	....		4	4½	81	4	Medium or late; prolific and well filled.
			4	2	5	0	....						
			3	3	1	8	....						
			5	0	5	0	....						
			4	4	4	5	....						
Red Cob	74	30	5	7	4	7	....		5	0	77	4.5	Tall stalks, large ears; late to medium.
			5	2	5	6	....						
			4	0	....		....						
			5	0	4	3	....						
			6	2	5	0	....						
Tennessee White.	92	30	4	10	5	0	....		4	8	65	4.5	Small eared; prolific.
			5	0	6	2	....						
			7	0	4	0	....						
			4	10	4	0	....						
			4	0	1	3	....						

Notes on varieties of cotton.

Cotton.
- Field No. (Row) 6.
- Variety: Dickson Cluster.

I. Bolls, position.
- Cluster, semicluster, noncluster: Cluster.
- Terminal or nonterminal, ———

II. Stalk..........
- Base limbs ..
  - Number: 2 to 5, generally 2 to 3.
  - Length: Medium.
  - Internodes: Medium.
- Upper limbs—Length: Short.
- Compactness: Erect.
- Height: Medium.

III. Bolls..........
- Weight .....
  - 10.
  - 10.
  - 10.
- Size (field estimate), ———
- Point: Both acute and blunt.
- Adherence, ———

IV. Seed
- Percentage of lint, ———
- Weight
  - 50.
  - 50.
  - 50.
- Shape and size, ———
- Color, ———

V. Earliness
- Field estimate: Very early.
- 3 best plants.

	a	b	c	Average.
Number open	54	29	31	38
Number grown Number younger	3	6	21	10
Total	57	35	52	48

Percentage of bolls open, 79.

VI. Prolificacy
- Selected plants (field estimate); percentage, 100.
- 3 best plants (office), ———

VII. Lint (field estimate), ———

THE COLLEGE OF AGRICULTURE OF THE UNIVERSITY OF ILLINOIS.

The college of agriculture is one of the six colleges of the University of Illinois. Candidates for admission to the college of agriculture are required to have the same number of high school credits as candidates for admission to other colleges of the university.

This number is 40 credits at the present time, but it will be increased to 42 credits in 1905. By the term credit is meant the work in a subject continuously pursued with daily recitations through one of the three terms of the high school year; or, in other words, the work of 60 recitation periods of forty minutes each, or, the equivalent in laboratory or other practice. Of the total number of credits required for admission, 9 must be in English, 7 in mathematics, and 6 in science and history. For graduation from the college of agriculture, students are required to have obtained 130 university credits. By the university credit is meant a class period a week for one semester, each class period presupposing two hours' preparation by the student, or the equivalent in laboratory, shop, or field practice. The work for 79 credits is prescribed as follows:

15 credits in agronomy.
5 credits in thremmatology.
2½ credits in animal husbandry.
2½ credits in dairy husbandry.
8 credits in horticulture.
15 credits in chemistry.
5 credits in geology.
5 credits in botany.
5 credits in zoology.
2 credits in economics.
6 credits in rhetoric.
5 credits in military science.
3 credits in physical training.

Of the remaining 56 credits required for graduation at least 4½ must be chosen in animal husbandry or dairy husbandry, 5 in natural history, 3 in English, and 25 in technical agriculture. The remaining credits may be obtained from any subjects offered in the university which the student is prepared to take, provided only that two years of foreign language must be taken in the university if not offered for admission. A thesis is also required for graduation for which from 5 to 10 credits will be allowed according to the nature of the subject.

The students in the college of agriculture are given courses in English or other languages in the college of literature and arts; courses in chemistry, physics, geology, botany, zoology, mathematics, etc., in the college of science; blacksmithing, carpentry, etc., in the college of engineering, the work of the college of agriculture being devoted to the subject of agronomy, animal husbandry, dairy husbandry, horticulture, and veterinary science, or, in other words, to the subjects in technical agriculture.

In the department of agronomy 15 courses are offered (not including the courses in farm mechanics), which are described briefly in the following excerpts from the college catalogue:

The semester, the days, and the class period or periods during which each course is given, and the number of credits per semester for which the course counts are shown after each course, as follows: The semester is indicated by the Roman numerals I, II; the days, by the initial letters of the days of the week; the class period or periods (of which there are nine each day, numbered consecutively from 1 to 9), by Arabic figures; and the amount of credit, by Arabic figures in parentheses. For example, the abbreviations I; M., W., F.; 1; (3) are to be read first semester, Monday, Wednesday, and Friday, first period, three credits.

1. *Drainage and irrigation.*—Location of drains and irrigation conduits, leveling, digging, laying tile and pipes, filling, and subsequent care; cost of construction and efficiency; sewers for the disposal of waste water from farm buildings and the sewage from kitchen and toilet; farm water pipes, pipe and thread cutting. Class work, laboratory and field practice. I; first half; daily; 6, 7; (2½).

5. *Farm crops—Quality and improvement.*—Judging of corn (see Exhibit 3, p. 30) and oats, wheat grading, methods of improving quality, shrinkage of grain, care of stored crops to prevent injury and loss. Class and laboratory work. I; first half; daily; 6, 7 (or 3, 4); (2½).

6. *Farm crops—Germination and growth.*—Vitality and germination of seeds, preservation of seeds, methods of seeding; conditions of plant growth; peculiarities of the different agricultural plants in respect to structure, habits, and requirements for successful growth; enemies to plant growth; weeds and weed seeds, their identification and methods of destruction; fungus diseases, such as smut of oats and wheat, and blight, scab, and rot of potatoes, methods of prevention; insects injurious to farm crops and how to combat them. Class room, laboratory, and field work. II; first half; daily; 6, 7; (2½).

7. *Special crops.*—A special study of farm crops taken up under an agricultural outline—grain crops, root crops, forage crops, sugar and fiber crops—their history and distribution over the earth, methods of culture, cost of production, consumption of products, and residues or by-products. Class work, supplemented by practical field work and a study of the results of previous experiments, such as detasseling corn, injury to roots of corn by cultivation, selection and breeding of corn and other crops, with special reference to practices which apply directly to Illinois conditions. Students will have an excellent opportunity to study the work of the Agricultural experiment station. II; daily; 1, 2; (5). Required: Agronomy 2, 5, 6.

8. *Field experiments.*—Special work by the students conducted in the field. This work consists in testing varieties of corn, oats, wheat, potatoes, and other farm crops;

methods of planting corn, seeding grains, grasses, and other forage crops; culture of corn, potatoes, and sugar beets; practice in treating oats and wheat for smut and potatoes for scab and studying the effects upon the crops; combating chinch bugs and other injurious insects. Other practical experiments may be arranged with the instructor. Special opportunities will be given to advanced students of high class standing to take up experiments, under assignment and direction of the instructor in farm crops, on certain large farms in the State, arrangements having been made with the farm owners or managers for such experiments. II, second half, and summer vacation; daily; arrange time; (2½ to 5).

Required: Agronomy 7, 12.

9. *Soil physics and management.*—This course is designed to prepare the student better to understand the effects of the different methods of treatment of soils and the influence of these methods upon moisture, texture, aeration, fertility, and production. It comprises a study of the origin of soils, of the various methods of soil formation, of their mechanical composition and classification; also soil moisture and means for conserving it, soil texture as affecting capillarity, osmosis, and diffusion, as affected by plowing, harrowing, cultivating, rolling, and cropping; of the wasting of soils by washing; fall or spring plowing and drainage as affecting moisture, temperatures, and root development. The work of the class room is supplemented by laboratory work, comprising the determination of such questions as specific gravity, relative gravity, water-holding capacity and capillary power of various soils; also the study of the physical effects of different systems of rotation and of continuous cropping with various crops, and the mechanical analysis of soils. I; daily; 1, 2; (5).

Required: Physics 1, 3 (first semester's work), and Agronomy, 2.

10. *Special problems in soil physics.*—This work is intended for students wishing to specialize further in the study of the physical properties of soils, and will include the determinaton by electrical methods of the temperature, moisture, and soluble salt content of various soils under actual field conditions; effect of different depths of plowing, cultivation, and rolling on soil conditions; effect of different methods of preparing seed beds; the physical questions involved in the formation and redemption of the so-called "alkali," "barren" or "dead dog" soils, and of other peculiar soils of Illinois. II, or summer vacation; daily; arrange time; (5).

Required: Agronomy 9.

11. *Soil bacteriology.*—A study of the morphology and activities of the bacteria which are connected with the elaboration of plant food in the soil, or which induce changes of vital importance to agriculture, with regard to the effects of cropping and tillage upon these organisms, and with special reference to the study of those forms which are concerned with the formation of nitrates and nitrites in the soil and with the accumulation of nitrogen by leguminous crops. Class room and laboratory work. II; daily; 6, 7; (5).

Required: Botany 5; Chemistry 3b, 4.

12. *Fertilizers, rotations, and fertility.*—The influence of fertility, natural or supplied, upon the yield of various crops; the effect of different crops upon the soil and upon succeeding crops; different rotations and the ultimate effect of different systems of farming upon the fertility and productive capacity of soils. The above will be supplemented by a laboratory study of manures and fertilizers, their composition and their agricultural and commercial value; of soils cropped continuously with different crops and with a series of crops; of the fertility of soils of different types, or classes from different sections of Illinois. II; daily; 1, 2; (5).

Required: Chemistry 13; Agronomy 6, 9.

13. *Investigation of the fertility of special soils.*—This course is primarily designed to enable the student to study the fertility of those special soils in which he may be particularly interested, and to become familiar with the correct principles and methods of such investigations. It will include the determination of the nature and

quantity of the elements of fertility in the soils investigated, the effect upon various crops of different fertilizers added to the soils, as determined by pot cultures, and, where possible, by plat experiments. This work will be supplemented by a systematic study of the work of experiment stations and experimenters along these lines of investigations. I, II; arrange time; (2 to 5).

Required: Agronomy 12.

14. *History of agriculture.*—Its development and practice, with particular regard to the agriculture of those nations which have contributed most to agricultural progress, including a sketch of the earliest agricultural practices as illustrated by the agriculture of the Egyptians, the Jews, the Chinese, and other ancient peoples; followed by a study of the development of Roman agriculture and its influences upon the practices in other nations; a consideration of the beginnings and systems of British agriculture with regard to their influence upon social conditions; and, finally, the development of modern agriculture with special reference to that of England, Germany, France, and the United States. I, second half; daily; 3; (2½).

15. *Comparative agriculture.*—Influence of locality, climate, soil, race, customs, laws, religion, etc., upon the agriculture of a country, and incidentally upon its people. One crop only, and its effect, as rice; Indian corn in American agriculture and affairs. Varying conditions under which the same crop may be produced, as wheat. Statistical agriculture. Influence of machinery and of land titles, whether resting in the government, in landlord, or in occupant. Relation of agriculture to other industries and to the body politic. Lectures. II; F; 4; (1).

Required: Two years of University work.

16. *German agricultural readings.*—A study of the latest agricultural experiments and investigations published in the German language, special attention being given to soils and crops. The current numbers of German journals of agricultural science will be required and used as a text. This course is designed to give the student a broader knowledge of the recent advances in scientific agriculture, and, incidentally, it will aid him in making a practical application of a foreign language. It is recommended that it be taken after Agronomy 12. II; M., W.; 4; (2).

Required: Two years' work in German.

17. *Special work in drainage and machinery.*—Students may arrange for special work in any of the lines covering drainage or farm machinery, either in the second semester or the summer. (2½ to 5.)

18. *Investigation and thesis.*—This course varies in the subject matter of study, according to the department in which theses are written. The work is under the direction of the head of the department. I, II; arrange time; (5 to 10).

The offices, class rooms, and laboratories of the department of agronomy are housed in the agricultural building (Pl. I), which was recently completed at a cost of $150,000. It consists of four separate structures built around an open court and connected by corridors. The main building is 248 feet long and from 50 to 100 feet wide, and three stories high. The other three buildings are 45 by 116 feet, and two stories high. These buildings are of stone and brick, roofed with slate, and contain, all told, 113 rooms and a total floor space of nearly 2 acres. An adjacent glass structure includes a photographic laboratory and a pot-culture laboratory for the department of agronomy. Several acres of land near to the agricultural buildings are used for instruction in agronomy, chiefly by means of student experiments.

Aside from the work in farm mechanics, the department of agronomy includes four principal divisions, viz, soil fertility, soil physics, soil bacteriology, and farm crops. Several courses of instruction are offered in each of these divisions, and in each case instruction is given by the laboratory method, as well as by text-books, lectures, and reference readings. Two laboratories are provided for the work in soil fertility. One of these is used for the analysis of soils, fertilizers, and manures; for the determination of the elements of plant food contained in plants and plant products, and for the preparation of soils for pot culture experiments, which include the use of sand cultures, water cultures, and soil cultures, with the addition or elimination of any or all of the different elements of plant food (Pl. III, fig. 1). The second is the pot-culture laboratory (Pl. III, fig. 2), which is located in the greenhouse near the agricultural building, and in which the pot-culture experiments are carried on by the student as a part of his regular laboratory practice. The soil fertility analytical laboratory is provided with desks for 18 students' places, each desk being made double, so that by working two sections 36 students can be accommodated. All apparatus necessary for the analysis of soils, fertilizers, etc., is provided, including analytical balances, digestion furnaces, distillation apparatus, glass and porcelain ware, etc. The laboratory is provided with a hood under which operations which give off poisonous or disagreeable fumes or odors are performed. The desks are piped for gas, compressed air, vacuum and water, and provided with sinks and waste pipes. The fertility pot-culture laboratory is provided with suitable tables and with several hundred glazed pots of different sizes suitable for pot-culture experiments. Most of the water used in the pot-culture experiments is drawn from a 400-barrel cistern, which is kept full of exceedingly pure soft water collected from the slate roof of the agricultural building, which is a quarter of a mile distant from the central heating plant of the university, and hence is very free from coal smoke, etc., from the chimneys. For special purposes, distilled water is provided and, when necessary, nitrogen-free water is used.

The soil physics laboratory (Pl. IV, fig. 1) is provided with a sufficient number of desks to allow 24 students to work at one time, and, by running two sections, 48 students can be accommodated. This laboratory is well equipped with the apparatus necessary for studying the physics of soil, including centrifugal machines and shaking apparatus used in mechanical analyses (fig 1), microscopes, balances, compacting apparatus, apparatus for determining the water content, absorptive capacity, water-holding power, and specific gravity of soils; several electrical instruments for the determination of temperature, moisture, and soluble salt-content of soils; a 3-horsepower electric motor with a line shaft, counter shaft, belting, etc.; elutriators, furnaces, sieves, and much other general apparatus. The laboratory is also provided with a side table, hood, large drying oven, and storeroom. For the work in farm drainage the department of agronomy is provided with several surveyors' leveling instruments, chains, and tapelines, and all necessary tools for running ditches and laying tile. Students are given a considerable amount of practice in surveying systems of drainage, running levels, digging ditches, and laying tile.

Two laboratories are provided for the study of soil bacteriology, although one of these is also used during part of the year for beginning students in general bacteriology. Thirty-two student places are provided for. The laboratory is equipped with incubators, microscopes, autoclaves and other sterilizing apparatus, balances, and other materials needed for bacteriological work, including staining solutions, chemicals, media, etc. The hood tables and the tile-top side tables are provided with steam baths, gas, air, vacuum, and water pipes, and waste sinks. Adjoining the laboratory are a store room, an incubating room, and an animal room with cages for keeping animals under experiment.

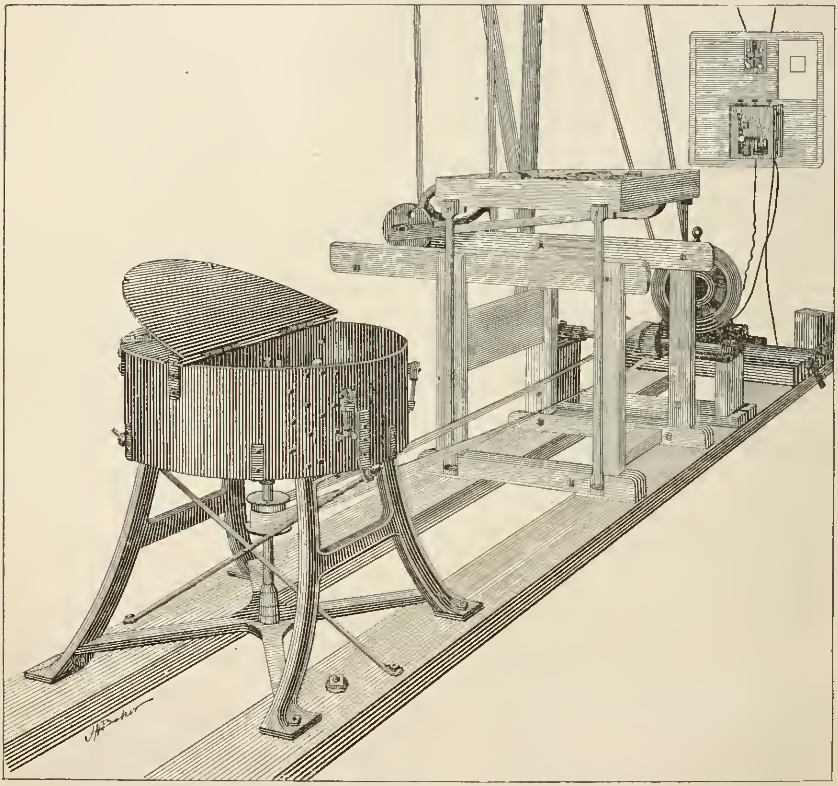
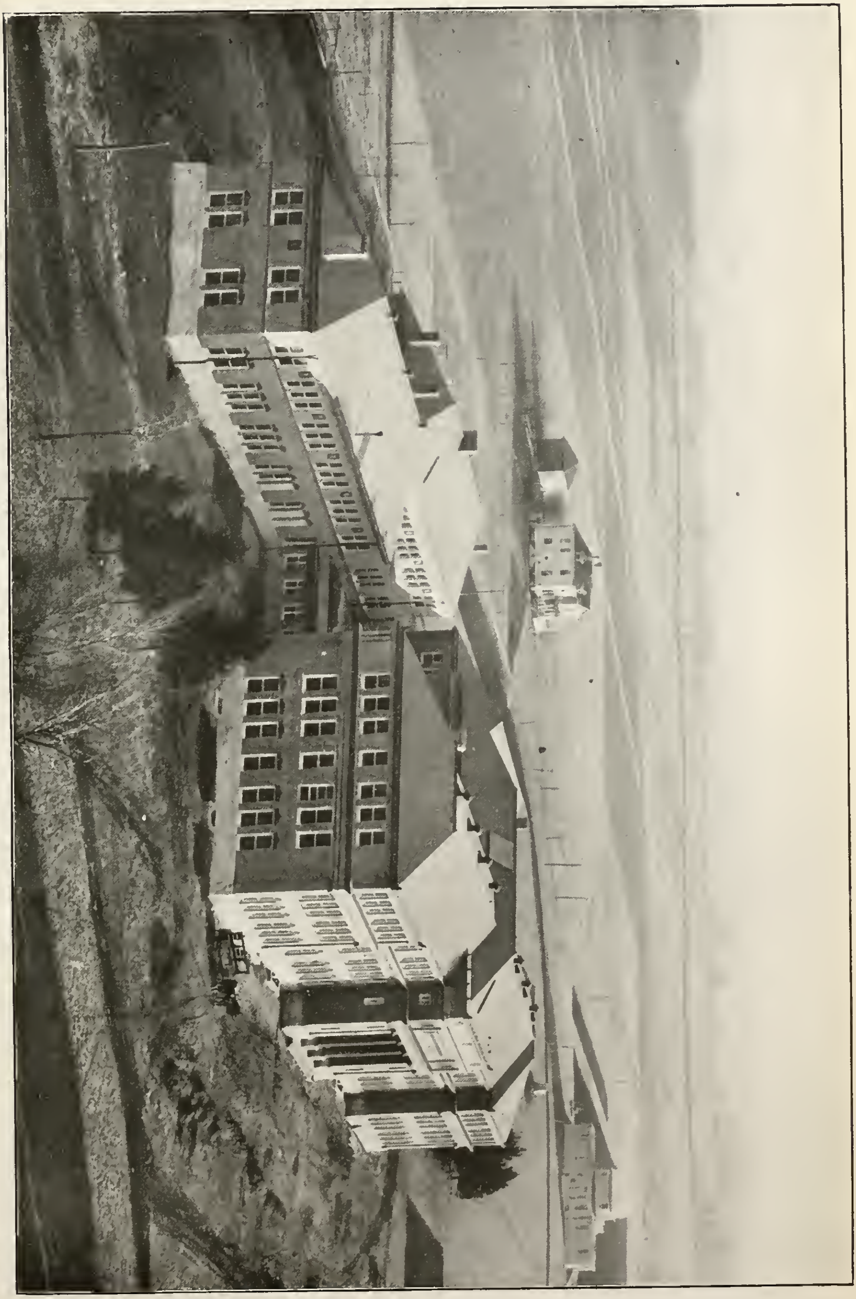


FIG. 1.—Centrifuge, shaker, and electric motor used in mechanical analysis of soils.

Two laboratories are provided for the work in farm crops (Pl. IV, fig 2), one of which has 36 student places, and the other 24 places,



UNIVERSITY OF ILLINOIS—BIRD'S-EYE VIEW OF AGRICULTURAL BUILDING AND EXPERIMENT FIELDS

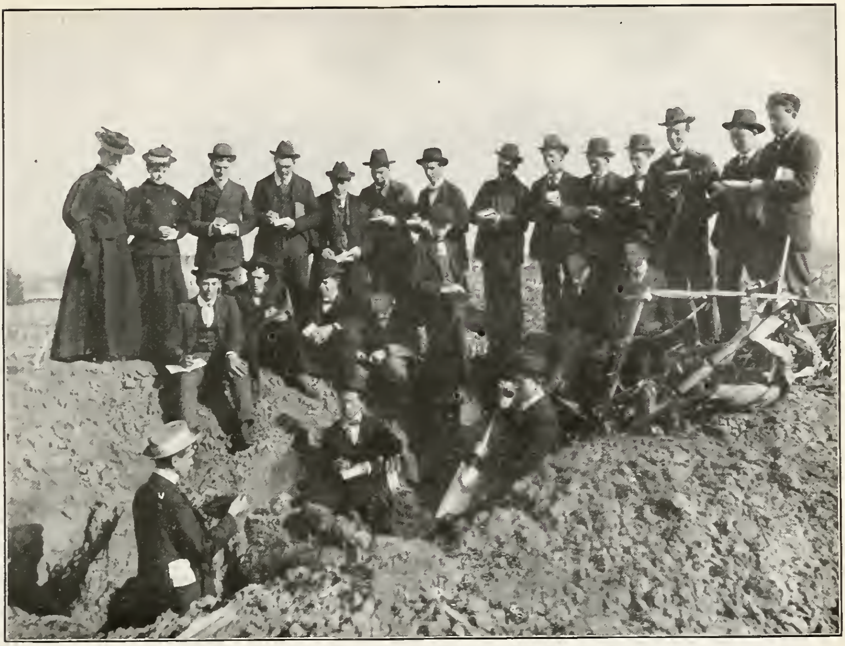


FIG. 1.—UNIVERSITY OF ILLINOIS—CLASS IN AGRONOMY STUDYING ROOT DEVELOPMENT OF CORN.

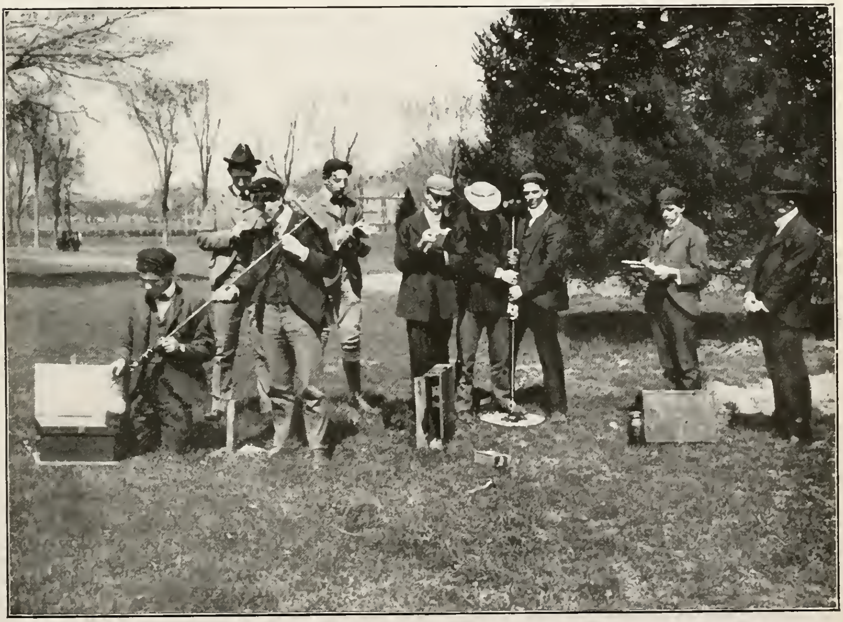


FIG. 2.—UNIVERSITY OF ILLINOIS—CLASS IN AGRONOMY COLLECTING SAMPLES OF SOIL.

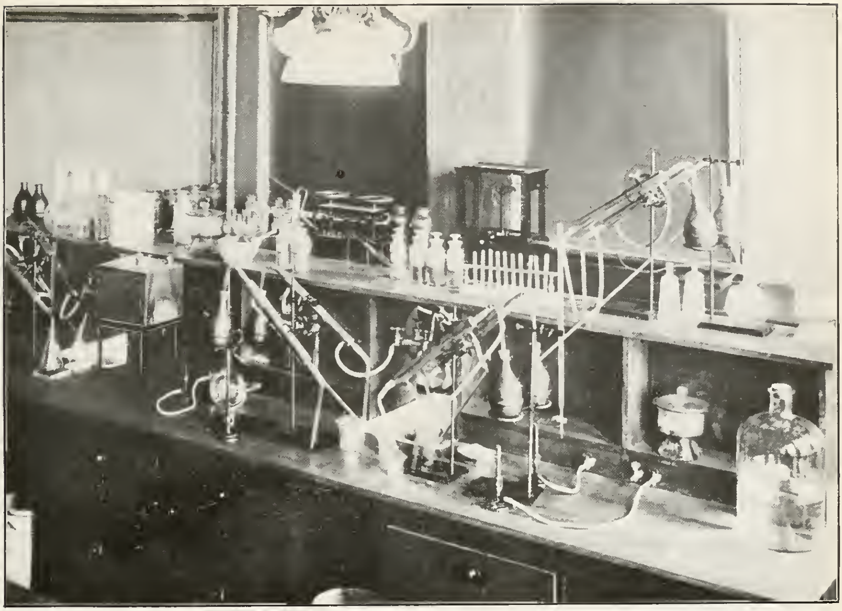


FIG. 1.—UNIVERSITY OF ILLINOIS—SOIL FERTILITY LABORATORY FOR ANALYSIS AND SYNTHESIS OF SOILS AND FERTILIZERS.

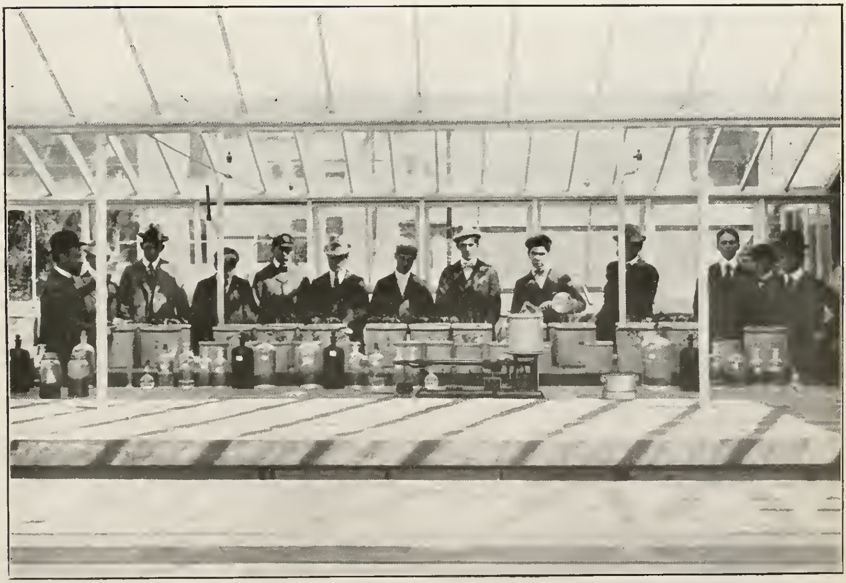


FIG. 2.—UNIVERSITY OF ILLINOIS—CLASS IN AGRONOMY IN POT CULTURE LABORATORY.

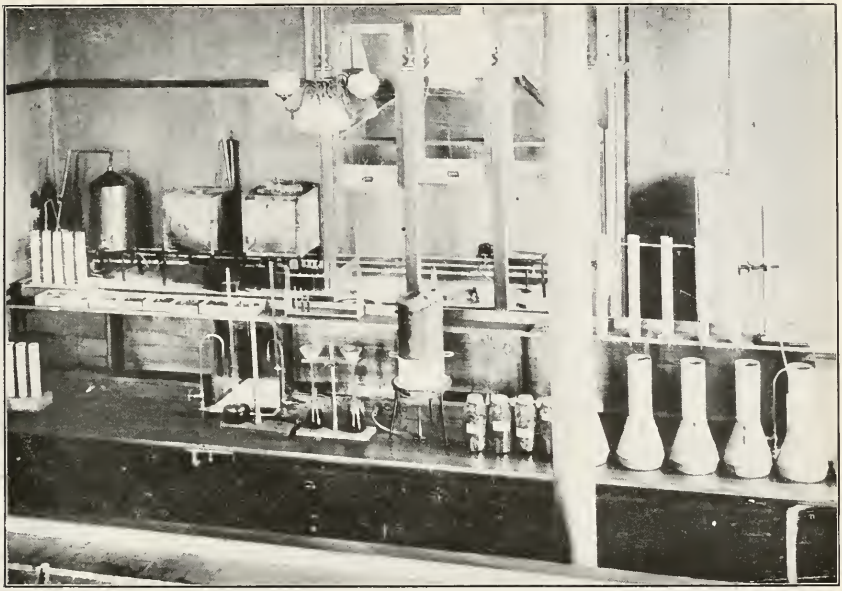


FIG. 1.—UNIVERSITY OF ILLINOIS—SOIL PHYSICS LABORATORY.

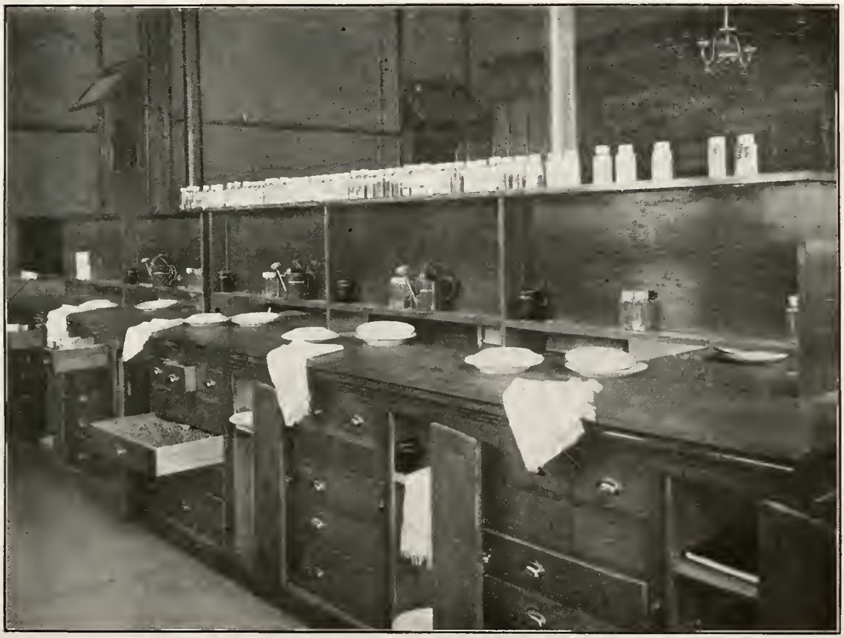


FIG. 2.—UNIVERSITY OF ILLINOIS—FARM CROPS SEED LABORATORY.

making it possible to have 60 students in farm crops at work at one time. These desks are provided with a large number of drawers for different samples of grains and equipped with small microscopes, tape measures, scales, germinating apparatus, etc. The laboratory is provided with one side case, containing 253 drawers for samples of corn of ten ears each, used in instruction in corn judging and the study of varieties of corn. There are a large number of tilting bins, holding from 1 to 3 bushels of corn, and a large wall case contains six upright bins, reaching nearly to the ceiling of the room, each of several bushels' capacity, used for holding a supply of some of the stock grains used in the farm crops work. There are six large herbarium cases for preserving specimens of different farm crops and of weeds injurious to farm crops. There is also a cabinet provided with a large number of cases for a collection of insects injurious to farm crops. Adjoining the farm crops student laboratory is a large germinating room, about 7 feet wide and 20 feet long, with wide shelving around the walls, extending from near the floor to the ceiling, giving sufficient space for several hundred germinators. This room is provided with steam coils with valves so arranged that any number of coils can be used and the temperature of the room regulated as may be desired. A large electric incubator is also provided for special germination studies. Besides the laboratory practice the students in farm crops carry on plat experiments under field conditions, several acres being provided for this purpose and hand tools being provided for student use.

Among the text-books and reference books most largely used in the course in soil fertility are Aikman's Manures and the Principles of Manuring, Voorhees's Fertilizers, Roberts's Fertility of the Land, Johnson's How Crops Feed, Snyder's Chemistry of Soils and Fertilizers, Storer's Agriculture, Liebig's Agricultural Chemistry, Lawes and Gilbert's Reports on Agricultural Investigations at Rothamsted, and the bulletins and reports of the United States Department of Agriculture and of the various State experiment stations.

Among the books used in soil physics are The Soil and The Physics of Agriculture, by King; Rocks and Soils, by Stockbridge; Origin and Nature of Soils,[a] by Shaler; and Land Drainage, by Miles.

Books used in soil bacteriology are Manual of Bacteriology, by Sternberg; Conn's Agricultural Bacteriology; and Fischer's Structure and Functions of Bacteria.

Among the books used in the study of farm crops are Johnson's How Crops Grow; Beal's Grasses of North America; Corn Plants, by Sargent; Plant Breeding, by Bailey; Weeds and How to Eradicate Them, by Shaw; and Storer's Agriculture.

In addition to these books the library of the University of Illinois contains several hundred volumes, journals, and pamphlets, in English, German, and French, relating in part or wholly to the subject of agronomy. These are accessible to all of the students in the department, but are used more largely by students engaged in research work.

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[a] Twelfth Annual Report of the U. S. Geological Survey, Part I—Geology, pp. 213–345.

Laboratory, lecture, or field notebooks are required to be kept by students in all courses in agronomy, and in most courses students are required to prepare two or three essays of from 1,000 to 5,000 words each during the semester. As a rule, preliminary examinations are given at the end of each month and a final examination at the close of the course. The student's standing or grade for the semester's work is based upon four factors: (1) Class records of recitations; (2) preliminary examinations and written exercises; (3) lecture, laboratory, or field notebooks; and (4) final examinations.

During the past year about 200 students took work in courses in agronomy. Advanced classes numbered from 12 to 25 students and lower classes contained from 30 to 75 students. Excursions are occasionally made by classes to examine soils, inspect drainage systems, to visit fields and other places of special interest and importance to the work of the classes.

Aside from the help of several student assistants, there are six regular instructors in the department of agronomy. One offers courses in soil fertility, another in soil physics, a third in farm drainage and irrigation, a fourth in soil bacteriology, and two other instructors give courses in farm crops.

EXHIBIT No. 3.

JUDGING CORN.

Students in farm crops, when judging corn, are provided with stiff cardboard covers 9 by 4¾ inches, in which special blank forms for scoring may be fastened. On the inside of the front cover is pasted Form A, giving standards for varieties, explanation of points, and rules to be used in judging. On the inside of the back cover and fastened to it by brass paper fasteners are forms B and C. Form B is used by the student in scoring a single ear of corn, and Form C for recording the corrected scores of several ears.

FORM A.—*Directions for scoring.*

STANDARDS FOR VARIETIES.

Name of variety.	Length of ear.	Circumference of ear.	Proportion of corn to cob.
	Inches.	*Inches.*	*Per cent.*
Reid Yellow Dent	10	7	88
Golden Eagle	9	7	90
Riley Favorite	9	7	90
Leaming	10	7	88
Boone County White	10	7.5	86
Silver Mine	9	7	90
White Superior	8.5	7	88
General	10–11	7.5–8	88

EXPLANATION OF POINTS.

1. Uniformity: Uniform shape, size, indentation, and type of ears.
2. Shape: Shape of ear should conform to variety type, usually cylindrical, i. e., of equal circumference from butt to tip.
3. Color: Free from mixture and true to variety color.
4. Market condition: Ripeness, soundness, ear firm and well matured.
5. Tip: Kernels filled over the tip in regular manner.
6. Butt: Kernels swelled about ear stalk, leaving deep depression when shank is removed.
7. Kernel, uniformity: Uniform shape, size, and conformity to variety type.
8. Kernel, shape: Wedge shaped, straight edges, and large germ.
9. Length: Varies with the variety, measure.
10. Circumference: Varies with the variety, measure.
11. Space: Furrow between tops of rows of kernels.
12. Proportion: Proportion of weight of grain to cob. Weight varies with variety.

RULES TO BE USED IN JUDGING.

1. The deficiency and excess in length of all ears not conforming to the standard for the variety shall be added together, and for every 2 inches thus obtained a cut of one point shall be made. In determining length, measure from the extreme tip to the extreme butt.

2. The deficiency and excess in circumference of all ears not conforming to the standard of the variety shall be added together, and for every 4 inches thus obtained a cut of one point shall be made. Measure the circumference at one-third the distance from the butt to the tip of the ear.

3. In determining the proportion of corn to cob, weigh every alternate ear in the exhibit. Shell and weigh the cobs, and subtract from weight of ears, giving the weight of corn. Divide the weight of corn by total weight of ears, giving the per cent of corn. For each per cent short of standard for the variety a half-point cut shall be made.

4. In judging color, a red cob in white corn, or a white cob in yellow corn, shall be cut ten points. For one or two mixed kernels, a cut of one-fourth point; for three or four mixed kernels, a cut of one-half point; for five mixed kernels, a three-fourths-point cut; or for six or more mixed kernels, a one-point cut shall be made. Kernels missing from the ear shall be counted as mixed. Difference in shade of color, as light or dark red, white or cream color, must be scored according to variety characteristics.

5. To determine the cut for space, the following rules can be applied if combined with the judgment of the student: For less than one thirty-second inch, no cut; for a furrow one thirty-second to one-sixteenth inch, one-half point; for more than one-sixteenth inch, cut one point. The looseness of kernels on the cob does not apply to space, but to maturity. The furrows or angle between the tops of the rows of kernels is the space between rows.

Form B.—*For individual sample.*

STUDENT'S REPORT JUDGING CORN.

Date, ——— —, ——.
Number of exhibit, ———.
Name of variety, ———.

STANDARD OF VARIETY.

Length, ———.
Circumference, ———.
Proportion grain to cob, ———.

	Points.	Student's score.	Corrected score.	Instructor's score.
1. Uniformity	10			
2. Shape	5			
3. Color	10			
4. Market condition	5			
5. Tips	10			
6. Butts	5			
7. Kernel uniformity	5			
8. Kernel shape	5			
9. Length	10			
10. Circumference	5			
11. Space	10			
12. Proportion	20			
Total	100			

REMARKS.

———————————————————————
———————————————————————

Form C.—*For several samples.*

	Points.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1. Uniformity	10																									
2. Shape of ear	5																									
3. Purity of color	10																									
4. Market condition	5																									
5. Filling out tips	10																									
6. Filling out butts	5																									
7. Kernel uniformity	5																									
8. Kernel shape	5																									
9. Length	10																									
10. Circumference	5																									
11. Space between rows	10																									
12. Proportion of corn to cob	20																									
Total	100																									

Exhibit No. 4.

STUDENT'S LABORATORY BLANKS IN SOIL PHYSICS.

Experiment No. 1.

MOISTURE—CAPILLARY.

Use sand, clay, loam, and gravel as provided.

1. Weigh carefully four drying pans.

2. Place in one of each about 100 grams of each of the above soils.

3. Weigh the pan and soil carefully.

4. Spread out the soil to a thin layer by shaking, and dry for twenty-four hours at room temperature.

5. Weigh and repeat the drying and weighing at intervals of four to five hours until a nearly constant weight is obtained.

The loss of weight represents the amount of capillary water.

Amount of capillary water found was: Sand, ———; clay, ———; loam, ———; gravel, ———.

Define capillary water: ——— ———. ——— ———.

Experiment No. 2.

DETERMINATION OF HYGROSCOPIC MOISTURE.

Use the air-dried soils from experiment No. 1.

1. Place about 10 grams of the air-dried soil in a tared porcelain crucible (*a*).

2. Weigh the soil and crucible (*b*) and heat in the air bath at 100 to 110° C. for 1 hour.

3. Cool in a desiccator and weigh rapidly to prevent absorption of moisture from the air.

4. Heat for a shorter time, cool, and weigh, repeating until the weight (*c*) becomes constant.

Calculation: The loss of weight, or $b—c$, equals the amount of hygroscopic water in the sample taken.

$c-a$ equals the weight of water-free soil.

Therefore $\frac{b—c}{c—a}$ = per cent of hygroscopic water expressed on the basis of water-free soil.

The per cent of hygroscopic water found was: Sand, ———; clay, ———; loam, ———; gravel, ———.

Define hygroscopic water: ——— ———.

From the results obtained in experiments 1 and 2 compute the percentage of capillary and total water in the soil, expressed on the basis of water-free soil.

Total water content is (percentage). Sand, ———; clay, ———; loam, ———; gravel, ———.

——— ———.

In addition to the capillary and hygroscopic water, the soil may contain, under some conditions, as immediately after a rain, a certain amount of free or gravitational water. This portion of the soil water is acted upon by the force of gravity, which causes it to percolate downward to the level of the ground water.

Experiment No. 3.

HILGARD'S FLOCCULATION EXPERIMENT.

Two students will work conjointly in this experiment.

1. Into each of four beakers place about 1 gram of clay and add 200 cubic centimeters of water.

2. To beaker—
   - No. 1 add 0.2 gram calcium hydrate=0.1 per cent solution.
   - No. 2 add 1 gram calcium hydrate=0.5 per cent solution.
   - No. 3 add 2 grams calcium hydrate=1 per cent solution.
   - No. 4 add 0 gram calcium hydrate=Control.

3. With a stirring rod mix the contents of each beaker thoroughly and then place a sample of each in a Nessler's cylinder and whirl in the centrifuge at the lowest speed and note the time required to completely precipitate each solution.

4. Pour the contents of each cylinder back into the respective beaker, stir thoroughly and set aside, observing occasionally to determine the time required for complete sedimentation in each case.

Compare in each case the cylinders and beakers containing the different strengths of solution and the control and tabulate the results in the space below.

	Time to centrifugate.	Time to sediment.
0.1 per cent solution	....	....
0.5 per cent solution	....	....
1 per cent solution............	....	....
Control	....	....

Explain how the lime acts and clarifies the water: ——— ———.

——— ———.

Experiment No. 4.

EFFECTS OF LIME ON PLASTIC SOILS.

Two students will work together as in experiment No. 3.

1. Weigh out five 50-gram samples of the clay soil.
2. To sample—
    No. 1 add 0.5 per cent calcium hydrate.
    No. 2 add 1 per cent calcium hydrate.
    No. 3 add 5 per cent calcium hydrate.
    No. 4 add 10 per cent calcium hydrate.
    No. 5 add no calcium hydrate.
3. Mix each sample thoroughly in a soil pan, and add just enough water to make plastic.
4. Fill into molds in the form of sticks, using care to compress all samples to the same degree, and transfer to the oven and bake at 110° C. for 4 to 5 hours.
5. Test the strength of each stick of baked clay by supporting upon blocks and suspending weights until the clay is fractured. Note weight required in each case and fill in results below:

	Grams.
0.5 per cent broke with..	
1 per cent broke with..	
5 per cent broke with..	
10 per cent broke with..	
Control broke with..	

Explain the loss of plasticity due to the lime: ——— ———.

——— ———.

Experiment No. 5.

DETERMINATION OF THE APPARENT SPECIFIC GRAVITY OF SOILS.

Use each of the four soils as in former experiments.

1. Weigh carefully in empty and thoroughly cleaned soil tube (*a*).
2. Fill it with one of the soils to be tested, which must first be well pulverized if lumpy. In filling use the soil-compacting machine, allowing the weight to fall three times from the 6-inch mark upon each cupful of soil. Fill the tube to the crease near the top.
3. Weigh the filled tube carefully (*b*).
4. The area of the bottom of the tube is 20 square centimeters. From this compute the number of cubic centimeters of soil which it contains (*c*).
5. Determine the amount of hygroscopic moisture in a special sample of the soil, according to direction given under Experiment No. 2 (*d*).

Calculations—

$$b-(a+d)=\text{weight of the given volume of soil.}$$

Therefore, $\frac{b-(a+d)}{c}$=weight of 1 cc. of soil=volume weight of soil.

$$\frac{\text{Volume weight of soil}}{\text{Volume weight of water}}=\text{apparent specific gravity.}$$

I find the apparent specific gravity to be as follows: Sand, ———; gravel, ———; loam, ———; clay, ———.

The volume weight or apparent specific gravity of soils varies with the amount of packing, a freshly plowed field being much lighter per cubic foot than one compacted by rains or tramping.

Explain the object of using the soil-compacting machine in this experiment. ——— ———,

——— ———

Experiment No. 9.

DETERMINATION OF THE POWER OF LOOSE SOILS TO RETAIN MOISTURE.

1. Place 100 grams of the air-dried soil in a beaker and add 100 cubic centimeters of distilled water.

2. Mix the soil and water thoroughly and rinse the soil upon a previously saturated filter with a known amount of distilled water. Cover the top of the funnel with a glass plate to prevent evaporation.

3. Catch the water which drains away, in a graduate, and deduct the amount of water caught from the total amount used. The remainder represents the amount retained by the soil.

4. With a special sample of the soil used determine the per cent of hygroscopic water.

Calculation.—After finding the per cent of hygroscopic water, determine the amount of water-free soil in the 100-gram sample taken. Add the total amount of hygroscopic water to the capillary water retained and divide the sum by the weight of water-free soil, and the quotient will represent the per cent of water held, calculated on the basis of water-free soil.

Per cent of water retained was: Sand, ——; clay, ——; loam, ——; gravel, ——.

Why do you use air-dried soil in this experiment? ——.

Why do you moisten the filter? ——.

—— ——.

Experiment No. 12.

DETERMINATION OF THE RATE OF PERCOLATION OF AIR THROUGH SOILS.

1. Fill the series of tubes provided for this experiment with the finely pulverized and sifted soils without compacting.

2. Attach the tubes successively to the aspirator and note the length of time required to force or draw 10 liters of air through each sample of soil. The aspirator weight must be started from the same height in each case.

This experiment illustrates the relative aeration of soils, a question which is of importance in connection with the subject of the growth and development of the nitrifying and other bacteria of the soil concerned in the production of plant food.

Time required for sand, ——; gravel, ——; loam, ——; clay, ——.

—— ——.

Experiment No. 13.

CAPILLARY ATTRACTION OF SOILS.

1. Close the lower end of 12 of the large glass tubes by a piece of thin muslin tied firmly to the tubes. The tubes are then filled with the finely pulverized air-dried soils, which have been carefully sifted to remove all small stones. These tubes are to be filled with each soil—No. 1, by simply pouring the soil as loosely as possible into the tube; No. 2, by compacting the soil gently by tapping the lower end of the tube upon the bench, and No. 4, by compacting the soil by ramming with a rod. Care must be taken to compact the different soils to the same degree, both in the jarring and ramming, by jarring or ramming each tube the same number of times.

The tubes are now placed in the supporting frame in such a manner that the lower ends shall dip one-half inch beneath the surface of a tray of water.

The experiment is now ready for observation at intervals of twenty-four hours, when the height to which the water has risen is carefully measured and recorded.

These observations should be taken daily for one week, and the results are to be noted below.

Day.		Sand.			Gravel.			Loam.			Clay.		
		No. 1.	No. 2.	No. 3.	No. 1.	No. 2.	No. 3.	No. 1.	No. 2.	No. 3.	No. 1.	No. 2.	No. 3.
1	Rise												
	Total height												
2	Rise												
	Total height												
3	Rise												
	Total height												
4	Rise												
	Total height												
5	Rise												
	Total height												
6	Rise												
	Total height												
7	Rise												
	Total height												

To obtain accurate and reliable results it is necessary to use great care in filling the tubes, observing in particular that there are no places where the column of soil is unevenly packed or broken by coarse material which will prevent the action of capillarity.

Experiment No. 14.

EFFECT OF CULTIVATION OR DUST MULCHES ON EVAPORATION OF WATER FROM SOILS.

Fill all the tubes with the fine prairie soils, using the compacting machine. All the tubes should be filled to the same level.

The conical bases of the tubes are then filled partly full of water, so that the water shall stand at the same level in each. Determine the level with the S-shaped glass tube, and measure the depth of water very accurately with the millimeter rule. The tubes are to be filled to the same level each day, and the amount of water added is carefully noted. This amount represents the water lost by evaporation. The tubes are treated as follows: Tube 1, control; tube 2, cultivated 1 inch; tube 3, cultivated 2 inches; tube 4, cultivated 3 inches; tube 5, cultivated 4 inches; tube 6, cultivated 5 inches.

The cultivation is performed each day by removing a layer of soil to the depth of cultivation used in the tube, and thoroughly mixing it, when it is replaced.

Each tube has an area of 80 square centimeters = 12.4 square inches = $\frac{1}{505858}$ acre, and the results are to be computed in tons of water evaporated per acre. The observations are to be taken for seven days and the results filled in below.

Depth of culture	0 in.	1 in.	2 in.	3 in.	4 in.	5 in.
Total number grams						
Tons per acre						

Experiment No. 15.

EFFECT OF ARTIFICIAL MULCHES UPON EVAPORATION OF WATER FROM SOILS.

This experiment is conducted in a similar manner to the last, excepting that the tubes are all filled to the same level and used as follows: No. 1, control; No. 2, 2 inches sand; No. 3, 2 inches clay; No. 4, 2 inches muck; No. 5, 2 inches sawdust; No. 6, 2 inches cut straw.

RESULTS.

	Control.	Sand.	Clay.	Muck.	Sawdust.	Cut straw.
Total number grams						
Tons per acre						

MICHIGAN AGRICULTURAL COLLEGE.

The agricultural course in this college requires four or five years for completion, depending on the preparation of the candidates for admission, and leads to the degree of bachelor of science. The entrance examinations for the five-year course cover the following subjects: Arithmetic, geography, grammar, reading, spelling, penmanship, and history of the United States. The holder of a teacher's certificate, or eighth-grade diploma signed by a county commissiner and issued by a school following the course of study outlined by the State superintendent of public instruction, will be admitted to the five-year course without examination. For admission to the four-year course, students must hold diplomas from high schools on an accredited list, or must, in addition to the requirements named above, pass examinations in algebra through quadratic equations, in plane geometry, in elementary physics, and in English. Candidates for admission must bring testimonials of good character, and must be not less than fifteen years of age.

The entrance requirements also presuppose that the applicant has the ability to harness and drive horses, to plow, harrow, mark corn ground, drill, operate the mower, reaper, and farm implements generally, and to perform in a neat and workmanlike manner the details of regular farm work. A failure to pass this examination will not exclude from the college; another opportunity will be provided at the close of the second year to pass on these studies. If the student then fails he will be required to remain at the college during the summer vacation between his second and third years, or to work for the same period on some farm approved by the professor of agriculture. He will receive his final examination on the subject at the beginning of the junior year.

Since both the four-year and the five-year courses cover practically the same ground in agricultural subjects, only the four-year course will be described.

The course is centered around instruction and practice in agriculture and horticulture and the sciences directly bearing upon successful farming. It includes the following credits: Agriculture, 60; agriculture or horticulture (elective), 59; anatomy, 10; bacteriology, 14; bacteriology (elective), 24; botany, 56; botany (elective), 12; chemistry, 42; chemistry (elective), 12; civil engineering, 6; civil engineering (elective), 24; drawing, 10; economics (elective), 12; English, 59; English (elective), 12; entomology, 12; geology (elective), 10; German (elective), 60; history (elective), 12; horticulture, 51; hygiene, 4; mathematics, 29; meteorology (elective), 12; military science and tactics, 22; physics, 20; physics (elective), 12; political science, 10; psychology (elective), 12; sanitary science, 6; veterinary science, 5; veterinary science (elective), 36; zoology, 20; zoology (elective), 12.

Until the end of the first term, junior year, all four-year agricultural students pursue exactly the same studies, but for the remaining five terms they specialize in their technical work, electing either agriculture, including dairying, stock-feeding, soil work, and farm crops, or horticulture, including vegetable culture, pomology, and floriculture.

Instruction in agronomy is given by the professor of agronomy and one assistant in the second and third terms of the freshman year, the first and second terms of the sophomore year, the second and third terms of the junior year, and the first, second, and third terms of the senior year, and is supplemented by instruction in botany, bacteriology, and chemistry.

The courses in botany (aside from those bearing on forestry) for agricultural students include in the freshman year sixty-one hours of structural botany (gross anatomy and morphology of fruits and seeds) and thirty-three hours of systematic botany; in the sophomore year ninety-six hours of plant histology (use of compound microscope, preparation of slides, use of reagents, study of plant anatomy, etc.) and thirty-three hours of ecology; one hundred and twenty-six hours of fungi of economic importance during the first term of the junior year; and forty-eight hours devoted to a study of grasses and weeds during the second term of the junior year. A senior elective in plant physiology has been announced. Instruction in botany is given in the botanical laboratory, a building 55 by 45 feet, two stories with attic and basement. The basement includes a fire-proof room containing the herbarium of about 75,000 specimens, a lavatory, and large work-room for the preparation and storing of specimens and boxes; the first floor contains a dark room, two well-lighted rooms very fairly equipped for histological and physiological studies, and an office and laboratory for the professor in charge; the second floor contains a large room for beginners in botany and for lectures, and a study and laboratory for the assistants; the garret has recently been fitted for use as necessity may require.

Bacteriology is taught by the laboratory method, supplemented by such lectures as are necessary to direct the work. After one preliminary lecture course and two laboratory courses (first, morphological and cultural bacteriology, and second, physiological bacteriology), the student may elect during the winter term of the senior year a laboratory course in bacteriology (ten hours per week) devoted to the biological consideration of the soil. This work is given in a new and well-equipped bacteriological laboratory, which has just been completed at a cost (exclusive of equipment) of $25,000.

Instruction in chemistry includes general elementary chemistry (ninety-eight hours during the first term of the freshman year), qualitative analysis (one hundred and twenty hours during the second term of the freshman year), organic chemistry (ninety-eight hours during the first term of the sophomore year), and agricultural chemistry (sixty hours during the second term of the sophomore year and sixty hours, elective, during the second term of the senior year). The course in agricultural chemistry includes the history of agricultural chemistry; the composition of plants, sources of the organic constituents of plants, how to increase their quantity and availability; the soil and the influence of physical agencies on its chemical condition; the nature and action of the ash elements in plant growth; manures and manuring; intensive and extensive agriculture, and conservation of fertility; the chemistry of fodders and stock feeding, of ripening of fruits and grains. The aim in these lectures is to state and solve the chemical problems of the farm. The chemical laboratory building contains a lecture room for 150 students, analytical rooms fitted with evaporating hoods and tables for 68 students, the professor's private laboratory and study, and a suite of rooms for students in metallurgy and quantitative chemical analysis, and is well equipped with chemical apparatus and stores.

The courses in agronomy are introduced by a course of twenty lectures on the formation, character, and distribution of soils; the agencies still at work in soil formation and soil destruction; and the care required to be exercised to preserve the soils of agricultural districts. These lectures are given during the last four weeks of the second term of the freshman year and are illustrated by samples of soil, rock, etc., and by the stereopticon, and are supplemented by laboratory work and oral quizzes. During the third term of the freshman year, ten hours per week are spent in studying soils as regards their characteristics, functions, needs, and treatment in agriculture; drainage, its theory and practice; reasons for the different operations of the farm and the tools used; the planning of farm work, etc. Throughout this work the lantern is used to illustrate the talks and the student is taken to the tool room and to the field for observation. It is the aim to have quizzes at least as often as once per week.

Two hours daily of the first term of the sophomore year are devoted to lectures and laboratory work in agricultural physics, including (besides rural engineering and farm mechanics) laboratory work in the mechanical analysis of soils, the determination of moisture in soils, green and dry fodders, roots and grains, and experiments in moisture and air movements in soils.

The subject of farm crops is given in lectures five hours per week during the second term of the sophomore year. In this course, "good seed and conditions affecting its vitality, general requirements for successful plant growth, conditions governing the time and depth of planting, rate of seeding, etc., and the principles of plant improvement, are discussed. The history, distribution, general characteristics, adaptability, uses of the several farm crops, and the best method of producing them are studied."

In the second term of the junior year the student may elect "agricultural experimentation." In this course one hour per day is given to lectures and individual work on the part of the student on the experiment station work and literature of this and other countries, the organization and work of the United States Department of Agriculture, methods of experimentation, and the principles underlying the same. Each student is required in closing up the term's work to outline an experiment along some practical line of live stock, dairying, soils, or crops, and to submit the outline to the class for criticism and discussion. The experimentation is continued during the third term two hours per day. For example, the student electing an experiment in agronomy, such as tests of forage crop mixtures, variety tests of field crops, fertilizer experiments, etc., is allotted the necessary land, furnished team, implements, seed, etc., and is required to carry through his experiment and report upon it.

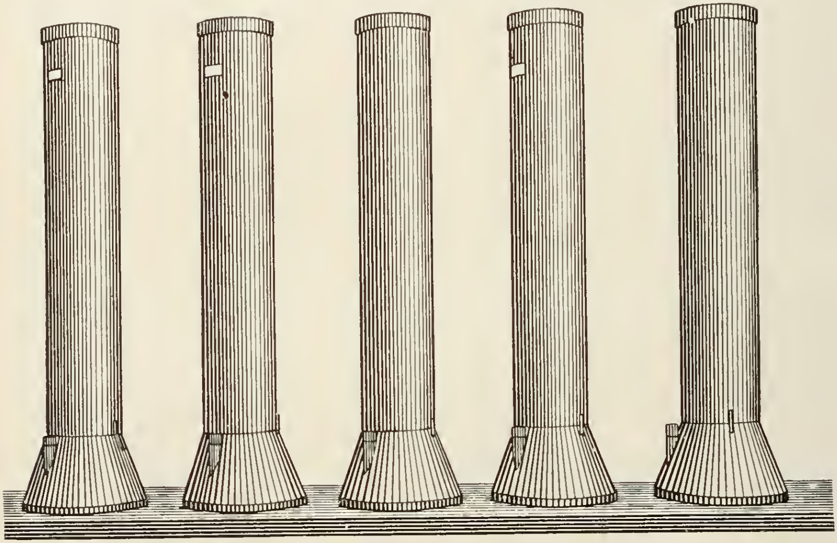
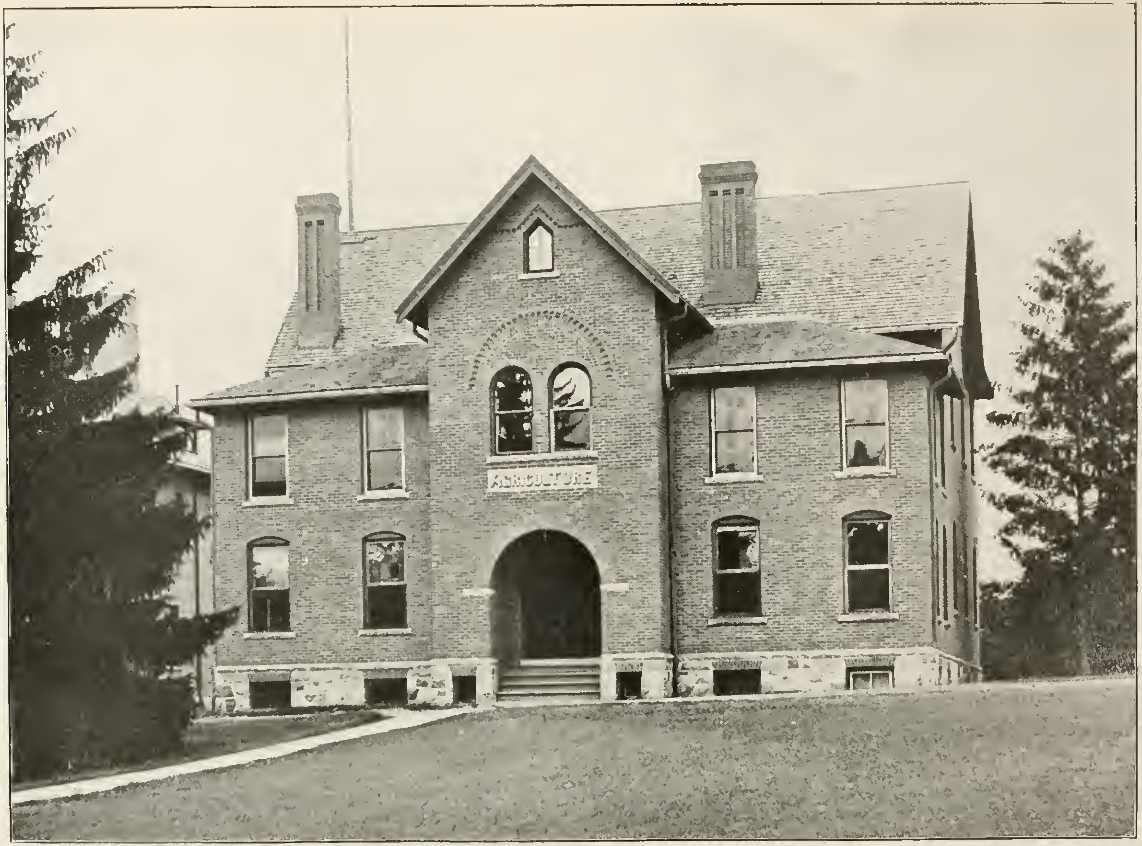


FIG. 2.—Tubes of galvanized iron used to study effectiveness of mulches upon moisture losses.

"The object of this work is twofold. To the young man going back to the farm it gives a training which enables him at once to pass upon the merits of any line of work described in station literature and to appropriate that portion of it which may be of value to himself; to the young man going into technical fields it gives a training which should give strength and reliability to his work."

In the senior year an elective in soil physics is offered. In this course ten hours per week during the first term are devoted to lectures and laboratory work, embracing a study of the physical properties and



AGRICULTURE

MICHIGAN AGRICULTURAL COLLEGE—AGRICULTURAL HALL.

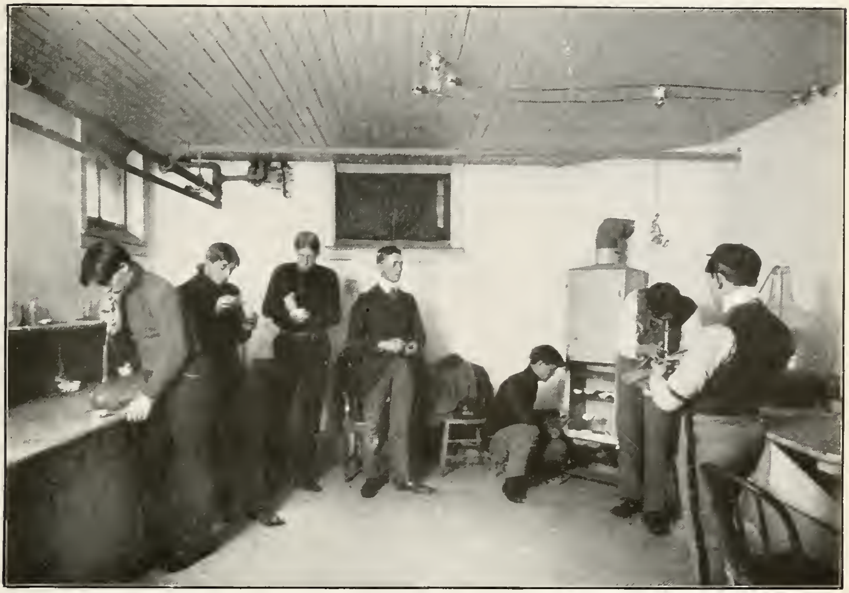


FIG. 1.—MICHIGAN AGRICULTURAL COLLEGE—STUDENTS MAKING MECHANICAL ANALYSES OF SOILS.

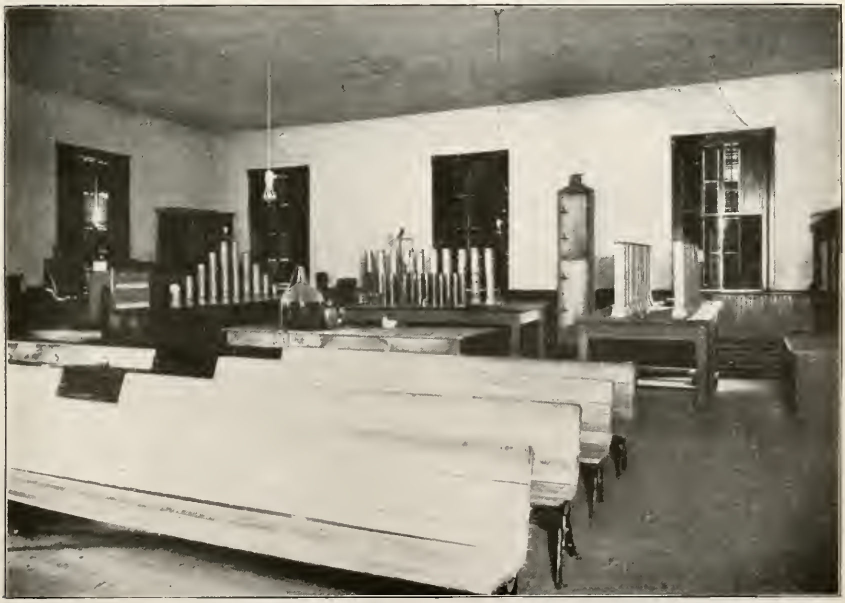


FIG. 2.—MICHIGAN AGRICULTURAL COLLEGE—SOILS LABORATORY AND CLASS ROOM.

characteristics of soils, such as determining the specific gravity, apparent specific gravity, water movements, capillarity, etc. During the winter term ten hours per week are devoted by the student to original investigation work along some line agreed upon between the student and professor in charge. During the spring term ten hours per week, seven weeks, are devoted to advanced work in soils, including lectures, laboratory work, studying soluble salts in soils by the electrical method, the pore space in natural soils, etc.

The building in which the instructional and laboratory work in agronomy is chiefly conducted is built of brick, is 53 feet long, 54 feet wide, and two stories high, with attic and basement, and is known as Agricultural Hall (Pl. V). The basement of this building contains a large laboratory for agricultural physics, a small laboratory for mechanical analysis of soils (Pl. VI, fig. 1), storerooms, etc., and connects with a small plant house. The first floor contains offices, a dark room, and a large general lecture room provided with 90 square feet of blackboard, two cases of wall maps, a stereopticon, and a 12 by 12 foot lantern screen. The windows of this and other rooms in the building are provided with cloth curtains and wood blinds. The lantern slides at present include illustrations of different phases of soil formation and soil destruction and of different kinds of farm machinery. New slides are being added. The soils laboratory, which also serves as a lecture room, is on the second floor of Agricultural Hall (Pl. VI, fig. 2) and is supplied with apparatus as follows: Four sets of galvanized iron tubes (fig. 2) for the study of moisture movements in soils and three sets of brass tubes for the study of water and air movements (figs. 3 and 4) in soils; a "King's aspirator" (fig. 3) for determining the effective size of soil grains; a "Whitney's bridge" for determining

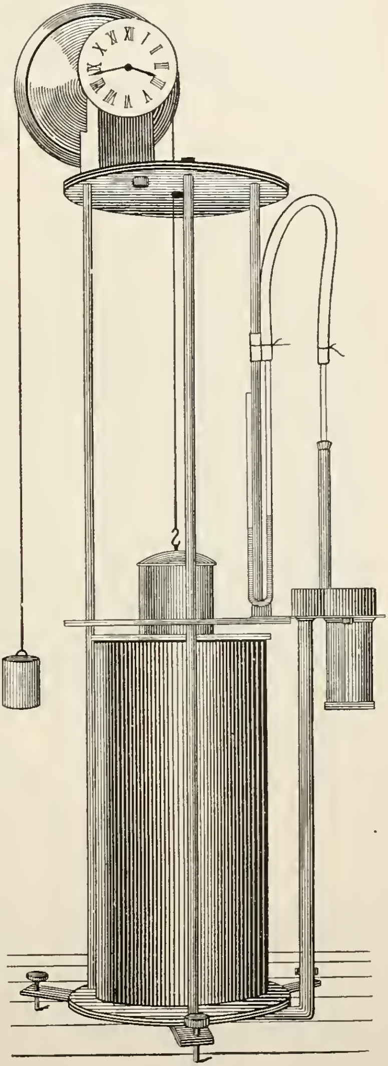


Fig. 3.—King's aspirator to determine the effective size of soil grains.

the soluble salts in soils; apparatus for the mechanical analysis of soils; a steam drying oven and a hot-air drying oven (fig. 6); trays and case, sampling auger, and sampling tube for field work in soils; a torsion balance and a number of other balances; four compound microscopes and one micrometer slide; a number of samples of typical soils from other States, as well as samples of Michigan soils, to which samples additions are being made as rapidly as opportunity permits; a grade level and rod; specific gravity bulbs, drying tubes, and sundry glass and rubber tubing and glassware. The room has about 120 square feet of blackboard.

The college farm comprises over 400 acres, not including the campus, orchards, gardens, stock yards, and the experiment station plats. It is divided into twenty pasture, field, and wood lots. At present the several acreages are about as follows: Woods, 140; wild pasture, 30; tame pasture, 37; hay, 69; and roots, cereals, and forage crops, 141 acres. The soil is a drift soil and ranges from a sandy soil to a fine clay soil, all of which is interspersed with coarse gravel and hard heads and bowlders. The farm machinery is up to date in every particular and includes a large collection of modern types of implements and machines, as well as some of the older types, which are used by the students in making comparisons of draft, work, effect on soils, etc.

The library contains over 21,000 bound volumes and about 5,000 pamphlets, and is rich in scientific works. The tables of the reading room are supplied with all the leading agricultural papers and journals. In matters concerning crops and soils reference is made, first of all, probably, to station literature, then to Storer's Agriculture, King's works, and others of Bailey's Rural Science Series, and the Rothamsted reports.

Exhibit No. 5.

A FEW OF THE PRACTICUMS IN AGRONOMY.

The movement of air through different soils.

Description of apparatus.—The apparatus used for the study of air movements through soils consists of an aspirator, as shown in fig. 4, and 12 brass tubes 16 inches in height and having a diameter of 3 inches. These soil tubes are all filled to the depth of 1 inch with a coarse sand, and above the sand are filled to a depth of 12 inches with the different soils indicated in the table. By means of apparatus prepared for the purpose the soils are introduced into the tubes and packed so that any difference in the pore space in the soils must be due to the physical properties of the soil. It will be seen that the variation of size of soil grain, variation in the proportions of large and small grains, variation in amount of organic matter present, etc., must be the factors resulting in the differences in the rates at which the air moves through the soil.

Observe that we have not the conditions in the soil in the cylinders that we have in the soil in the field, and that with this apparatus we are studying only the effects resulting largely from the properties named.

Details of the practicum.—

1. With the rubber tube detached from soil tubes, lift the aspirator weight, allowing bell to fall to bottom of aspirator tank.

2. Attach rubber tube to soil tube No. 1.

3. Now carefully lower weight until it is just sustained by pressure of air upon the bell.

4. With watch note time required for the hand to pass over three divisions of the dial, recording time as indicated in a table like the one below.

5. In like manner attach rubber tube to Nos. 2, 3, 4, 5, 6, 7, and 8 and note and record the time required to pass over three divisions of the dial.

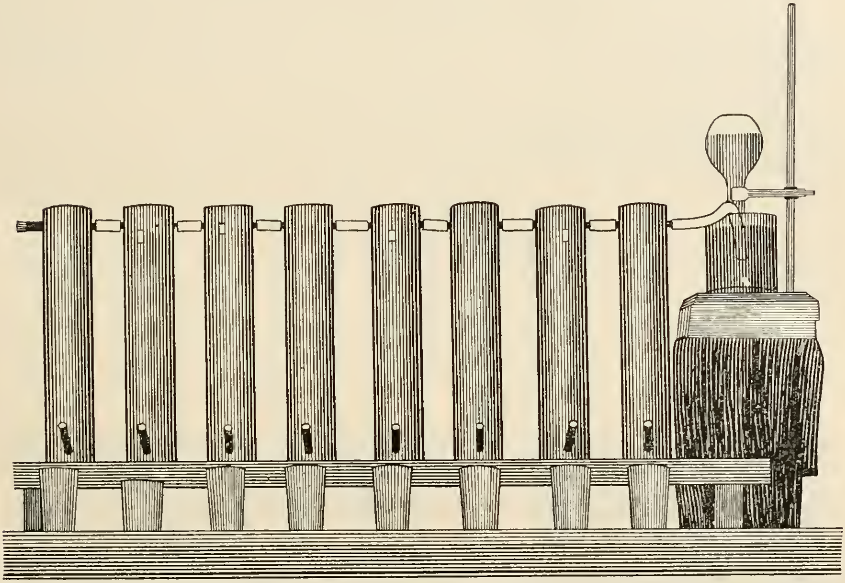


Fig. 4.—Apparatus used to study the movement of air through soils.

6. In like manner attach rubber tube to Nos. 9, 10, 11, and 12 and note the time required for the hand to pass over one division on the dial. Multiply this time by three and introduce in table.

7. Make computations and fill in as indicated in the table.

Soil.	Number of cylinder.	Time.				Relative rate of air movement.
		Initial.	Final.	Net.	Average.	
Sand	1					
	2					
Sand, with 3 per cent lime	3					
	4					
Peat	5					
	6					
Clay loam	7					
	8					
Clay, with 3 per cent lime	9					
	10					
Clay	11					
	12					

Percolation of water through different soils.

Description of apparatus.—This apparatus (fig. 5), consists of soil tubes similar to those used for the study of the rate of air movement through soils differing only in having tubes at the top by which the series may be connected by pieces of rubber tubing and supplied automatically with water so that the head or pressure in all the tubes can be kept constant. The tubes are filled in the same manner with soil as for studying air movements, and the rate of percolation depends upon the same physical properties of the soils as in the case of the movement of air.

Details of the practicum.—

1. See that the water supply is properly arranged.
2. Tare the glass or cylinder of each soil tube and record its weight in the proper place in a table like the one shown below, but do not return them immediately under the drain tubes.
3. Remove corks from drain tubes and insert wire drips.
4. When water drops from all the wires, place the glasses and cylinders quickly under the drain tubes, noting the time.

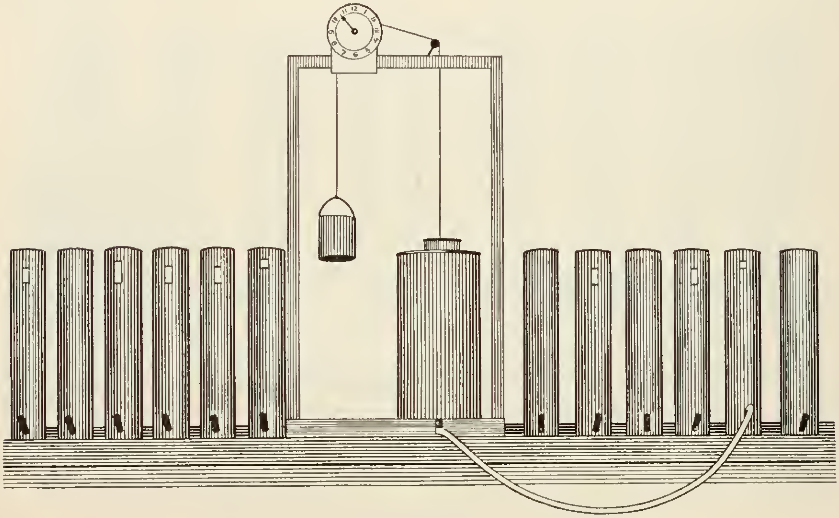


FIG. 5.—Apparatus used to study percolation of water through soils.

5. At the end of 45 minutes quickly remove glasses and cylinders.
6. Remove wire drips and insert corks in drain tubes.
7. Weigh glasses and cylinders with contents and record weights in the proper place in the table.
8. Make proper computations and introduce results in table.

Soil.	Number of cylinder.	Weight of empty cylinder	Weight of cylinder and contents.	Weight of water percolating in 45 minutes.	Average percolation in 45 minutes.	Relative rates of percolation.	Tons per acre per hour percolating.	Inches per hour percolating.
Clay								
Clay loam								
Sandy								
Peat								

Determination of soil moisture.

IN SOILS FREE FROM STONE.

To take samples:

1. Provide yourself with soil tube, mallet, and three soil trays.

2. Having determined place for taking soil sample, pack the surface of the soil lightly with the foot. Press or drive the tube into the ground until the 1-foot mark on the tube is even with the surface of the ground. Give the tube a turn. Place one hand firmly over the top of the soil tube to keep out air and with the other hand grasp and slowly withdraw the tube.

3. Remove cover from one of the trays, invert the soil tube, and allow the core to pass from the tube into the tray. Put cover on tray at once.

4. Return soil tube to the hole and press or drive down until the 2-foot mark on the tube is even with the surface of the ground. Remove as before and place the core in a second tray.

5. In like manner secure core from third foot and introduce into a third tray.

6. Pass to another point and as before secure cores of the first, second, and third foot, respectively, and introduce the cores into the trays containing the first, second, and third foot, respectively, already obtained.

7. Repeat until composite samples of four are obtained.

To dry samples:

8. Weigh each tray with contents, recording weights of each. Remove covers and place trays in drying oven.

9. After forty-eight hours replace covers and weigh trays with contents, carefully recording weights. Be sure samples are dry.

10. Remove the dry soil from trays, wipe the trays carefully and weigh, recording weight.

11. Determine (*a*) loss of moisture from the soil, (*b*) weight of dry soil, and (*c*) the per cent of moisture in each soil estimated on dry weight of soil.

IN ROCKY SOIL.

To take samples:

1. Provide yourself with two soil trays and a spade.

2. Having determined place to take samples dig a hole 1 foot deep and a little wider and longer than the width of your spade. See that one side is perpendicular. Remove all loose soil from bottom of hole.

3. With spade cut off a slice 1 inch thick from the perpendicular side of the hole to a depth of 6 inches, allowing soil to fall to the bottom of the hole where it should be quickly crumbled and mixed and freed from stones larger than a small marble.

4. Place about one-half pint of this soil in one of the trays and cover. Remove the rest of the soil from the bottom of the hole.

5. With spade finish cutting the slice to the depth of 1 foot and proceed as above to mix and free from stone.

6. Place one-half pint of this soil in the second tray and cover.

7. Selecting another point proceed as above to take samples of the first and second 6 inches, respectively, and place the samples so taken in the trays with the samples of the first and second 6 inches already taken, respectively.

To dry the samples:

8. Weigh each tray with contents, recording weights of each. Remove covers and place tray in drying oven.

9. After forty-eight hours replace covers and weigh trays with contents, carefully recording weights. Be sure samples are dry.

10. Remove the dry soil from trays, wipe the trays carefully and weigh, recording weight.

11. Determine (*a*) loss of moisture from soil, (*b*) weight of dry soil, and (*c*) the per cent of moisture in each soil estimated on dry weight of soil.

Determination of moisture in green crops, fodders, roots, and grains.

I.—PREPARATION.

(*a*) Green crops. Cut sample close to ground. Either fold or tie into short bundles or cut into short lengths and put into a tray.

(*b*) Fodder (including hay and straw). Cut a quantity of the material in a feed cutter or with a knife, mix well, and fill tray with sample.

(*c*) Roots. Select one or more typical roots, clean with a good brush or wash and wipe carefully. With a sharp knife slice in tray quickly and cover.

(*d*) Grain. Place about one pint of cleaned grain in a tray. If it is desired to determine the moisture of corn in the ear select a typical ear having all of its kernels and place in tray.

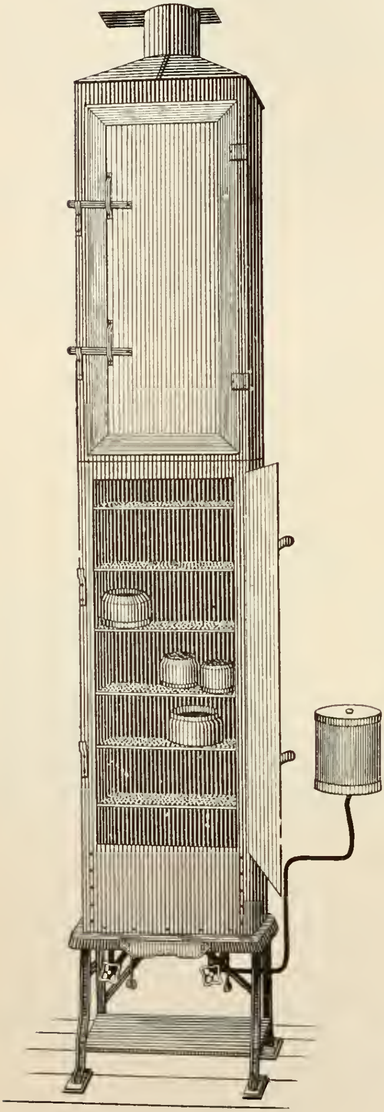


FIG. 6.—Hot-air drying oven.

II.—LABELING.

For the material placed in the trays it is sufficient to record the number of the tray.

Upon those materials not placed in trays a tag bearing your name should be placed.

III.—WEIGHTS.

You will need to determine: (*a*) Net weight before drying; (*b*) Net weight after drying; (*c*) Loss of moisture by drying.

With this data determine the per cent of moisture in the undried material.

IV.—THE DRYING.

Place material in hot-air oven (fig. 6) having temperature of 120° C. Drying should continue until materials have reached constant weights. This will usually be accomplished in twenty-four hours, but sometimes as much as forty-eight hours are required.

[Each student is given from six to eight materials to dry. In some cases he is required to go to the bin or field to procure them.]

Exhibit No. 6.

EXAMINATION QUESTIONS IN SOILS AND CROPS.

[This set of questions covers in a general way the work done during the spring term of the freshman year.]

1. What is meant by tillage? What are the chief objects sought in tillage? Tell quite fully how one of these objects is accomplished.
2. Explain the action of the common American plow. How does it differ from the English plow? Speak briefly of their relative merits. What objections to the common plow? What may we do toward obviating some of the bad effects?
3. Why do we cultivate? Describe an ideal cultivator and ideal cultivation.
4. What are some of the methods for removing the surplus water from land?
5. What will govern each of the following: Depth of drain, distance apart of drains, size of tile to be used.
6. What grade should tile drains have, what is the least grade allowable, and what precaution should be taken in laying a drain at such a grade?
7. How should laterals be connected with drains? Where and how should silt wells be constructed?
8. What is meant by rotation of crops? Why do we rotate at all?
9. Outline what you would call a good rotation, and give reason for the presence of each crop in the rotation.
10. When would you apply barn manure? At what rate, and why?
11. Speak of the value of clover as a crop. Why is it difficult to grow clover in Michigan? Tell how you would secure a stand of clover.
12. The effect of lime upon soils? Why? Would you apply lime to the soils of Michigan? If yes, at what rate and why? If no, why not?
13. What difference between a good truck soil and a good grass soil, and why is each soil especially adapted to its own crop?
14. In what way is the size of soil grain related to (*a*) the water holding capacity of the soil, (*b*) the plant feeding qualities, and (*c*) to the retaining of plant foods against percolation?
15. How does the amount of moisture required to grow a crop compare (*a*) with our annual rainfall, (*b*) with the water content of our soils in the month of March? What objections to summer fallowing?

COLLEGE OF AGRICULTURE OF THE UNIVERSITY OF MINNESOTA.

Candidates for admission to the College of Agriculture of the University of Minnesota must have the equivalent of either a three-year course in the school of agriculture plus one year of work of high-school grade in algebra, geometry, English, history, and economics, or a four-year course in a city high school plus one or two years in the school of agriculture. The school of agriculture is a technical high school, in which agriculture and subjects closely related to it largely predominate. These subjects include agricultural botany, chemistry and physics, dairy chemistry, agronomy, farm accounts, animal husbandry, dairy husbandry, fruit growing, vegetable gardening, etc., presented in a way to fit young men for successful farm life or for entrance to the college of agriculture.

The college course in agriculture is designed for those graduates of the school of agriculture and students from other institutions equally well prepared who desire further instruction in practical agricultural science, in the sciences related to agriculture, and in literature, and the arts. Since all students who enter this course have had the technical, scientific, and general work offered in the school of agriculture, the college course includes only advanced work of a collegiate grade. This course designs to efficiently prepare students for either farm life or for the work of the agricultural specialist. It emphasizes the importance of plant and animal production and the upbuilding of rural homes and farm life, while the biological and physical sciences are made prominent.

Following the four years of preparation in practical agricultural lines in the school of agriculture, the freshman and sophomore years are devoted largely to the study of the sciences. The technical subjects relating to agriculture and household economics are mainly offered as electives in the junior and senior years, when the freedom for election enables the student to choose as a specialty a major science or an agricultural or a household subject around which to group related elective subjects. The elective courses during the last two years give an opportunity for further culture in literary and philosophical lines and for becoming more proficient in scientific research work in some of the many problems pressing for solution in the development of the State and national agricultural experiment stations. The instruction in the various technical agricultural and household divisions in the college course is for the most part a continuation of the work in these subjects in the school of agriculture, each subject being treated from a more technical standpoint. Students who have first graduated from the agricultural school are ready in their junior and senior years to elect specialties for study and research work along lines in which they hope to work after graduation.

The subjects in the school of agriculture which more especially prepare for the collegiate work in agronomy are agricultural chemistry, agricultural botany, agricultural physics, and the subjects included under the title of agriculture.

Agricultural chemistry is divided into dairy chemistry; chemistry of foods, soils, and fertilizers, and domestic chemistry. Under the title of soils and fertilizers the student receives instruction in the composition of soils and their properties, the sources of plant food, the kinds and amounts of foods required by crops and the best ways of supplying these demands, the various forms in which plant food exists in the soil, farm manures, their uses and action upon the soil, the income and outgo of fertility from the farm, soil exhaustion and soil improvement, the rotation of crops, as based upon the chemistry of soils and the principles governing the conservation of the fertility of the soil. Laboratory practice forms an important feature of all the work in agricultural chemistry.

Agricultural botany is taught with special reference to its bearing upon the everyday problems that present themselves to the farmer and the gardener. By means of flowers and plants from the greenhouse and nursery, studied under the simple and the compound microscope, students are given a clear idea of the general principles of plant structure and vegetable physiology.

In agricultural physics the general principles of physics are taught, special stress being laid upon those principles which to the greatest extent enter into the business of the farmer. About half of the time is devoted to experimental work which includes capillarity of soil; diffusion and osmosis of gases and liquids; heating, lighting, and ventilation; farm machinery, in particular pumps, eveners, pulleys, milk testers, centrifugals, incubators, windmills, steam and gasoline engines; friction and lubricants; tensile strength of wire and binding twine of different grades; lightning and lightning protection.

The work designated "agriculture" in the school of agriculture includes (1) "introductory agriculture—soils; selecting and planting farms; subduing the fields; drainage; irrigation; fences; roads; buildings; water supply; groves and introductory lessons concerning farm business, farm life, and the relations of general science to agriculture;" and (2) field crops and farm management, comprising instruction in remodeling farm plans, production and management of farm manures, rotation and handling of field crops, care and use of pastures and meadows, weeds and their destruction, and the laws of heredity and variation in plant breeding, together with instruction in methods of breeding the leading field crops.

The college course in agronomy includes soil physics, field crops and seed, and plant breeding. Instruction in soil physics is given in the divisions of agricultural physics and agricultural chemistry, while that in field crops and seed and in plant breeding is given mainly by the professor of agriculture.

Under the head of field crops and seed are considered the botany, cultivation, use and place in the rotation of the various cereal, forage, root, fiber, sugar, and miscellaneous crops. Special attention is given to the subjects of permanent, rotation, annual, and shift pastures and to soiling crops; to permanent and rotation meadows, and to the production and preservation of all kinds of dry-cured and ensiled fodders. A thesis on one or more field crops is required of each student.

The work in plant breeding includes instruction on such subjects as heredity, variation, science of breeding, breeding as an art, improvement by nature and under scientific experimentation, securing foundation stocks, value of very large numbers, immense value of the occasional individual which can transmit qualities of peculiar value, use of an ideal, use and misuse of the score card, intrinsic qualities, fancy points and distinguishing marks, pedigree records of prepotency, fundamental principles underlying the arrangement of the record books, bibliography and terminology, study of the literature of breeding. Attention is also given to the botany of the reproductive organs of field crops, field-crop nursery management, producing new qualities by hybridizing and by change of environment, hybridizing versus crossbreeding, in-breeding and self-fertilization, originating varieties and improving standard varieties, methods of disseminating new varieties, seed and plant introduction, experimentation in the theories relating to heredity, variation and practical breeding, seed growing as a farm business, seed merchandising.

Elective practicums give opportunity to gain practical experience, to acquire greater manual dexterity in doing farm work, to secure practice in conducting experiments, and to gain experience in teaching agricultural subjects.

Agronomy is taught in dairy hall (Pl. VII, fig. 1) in temporary quarters which include one good recitation room, offices, and laboratory room. There is also a seed-breeding laboratory which furnishes facilities for special instruction in field seeds and in laboratory work in plant breeding. The college possesses a stereopticon with several hundred lantern slides, including illustrations of crops, implements, machinery, processes of drainage, etc.; imported models of wheat and of clover flowers and seeds; many charts of root systems and illustrations of floral organs which have been drawn at this institution; also maps and designs of farm plans, both for laying out new farms and for reorganizing old ones. Several hundred pasteboard boxes 24 inches long, 13 inches wide and 5 inches high, such as tailors use for suit boxes, are annually filled with bundles of weeds, grasses, and forage crops. These serve in the classes for material to tear apart, examine the seeds, and get acquainted with the general appearance. Seeds are also preserved in bottles. The collection of farm machinery in use at the university farm is supplemented by collections on exhibition at the State fair grounds, adjoining the farm, and at warehouses in St. Paul and Minneapolis.

One unique feature of the office equipment is a special index filing case. Here are collected newspaper clippings, manuscripts, and references to literature in the library. These are put on sheets, 5½ by 8½ inches, separated by division cards, and arranged under a scheme similar to that used by the Office of Experiment Stations in classifying special index cards of the station literature. This filing case now contains much material and is referred to constantly by students in the college course in writing essays and theses in connection with their class work. Each student who writes a thesis on a farm crop or other subject is required to furnish a copy for this filing case, and to include any bibliography he has been able to collect on that subject. Thus the students are assisting in building up the contents of this filing case and it is recognized by them as very valuable.

No text-books are as yet in use, instruction being given almost entirely by lectures. The agricultural library now contains 6,000 books and about 6,000 pamphlets, including reports and bulletins. Aside from the large number of pamphlets and other publications of the different agricultural institutions and societies, a large number of the more important technical and agricultural magazines are kept on file, bringing together all the agricultural literature of any importance.

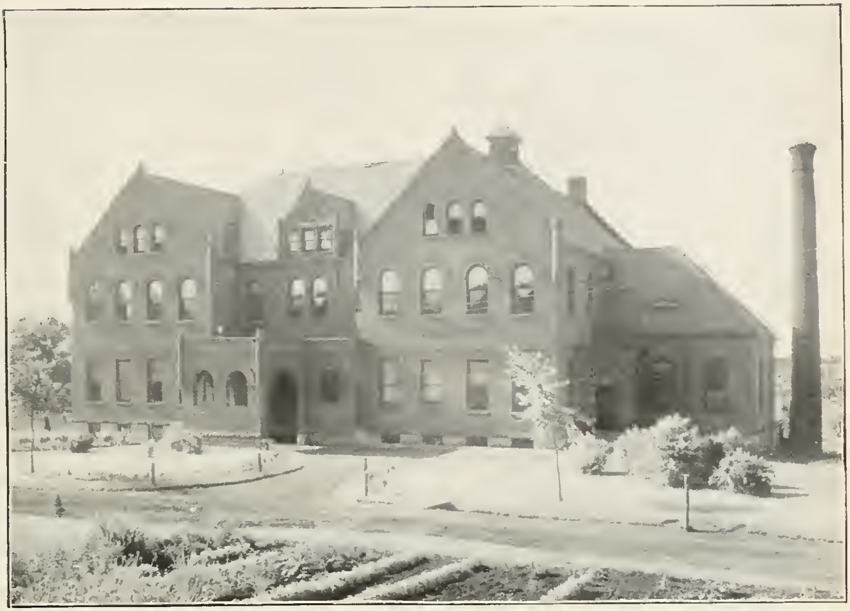


FIG. 1.—UNIVERSITY OF MINNESOTA—DAIRY HALL.

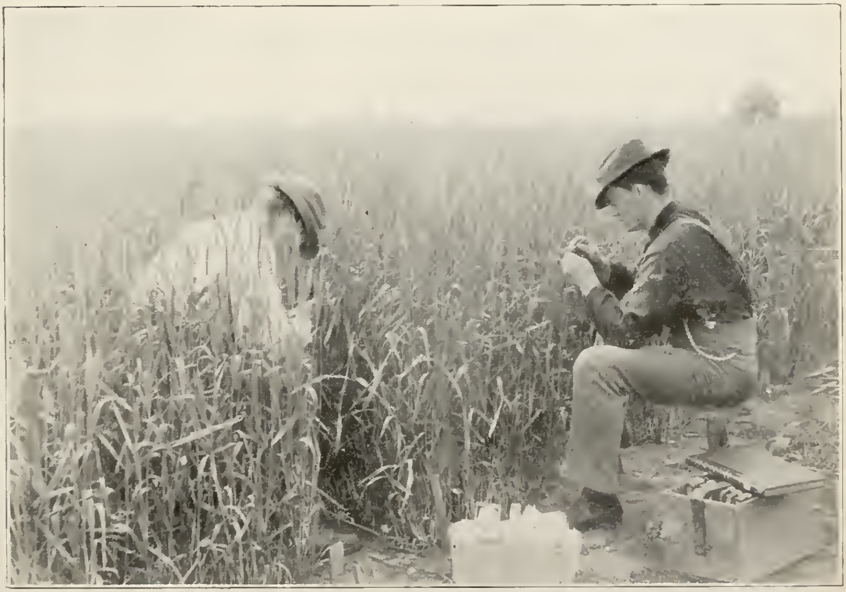


FIG. 2.—UNIVERSITY OF MINNESOTA—EMASCULATING AND CROSS POLLINATING WHEAT.

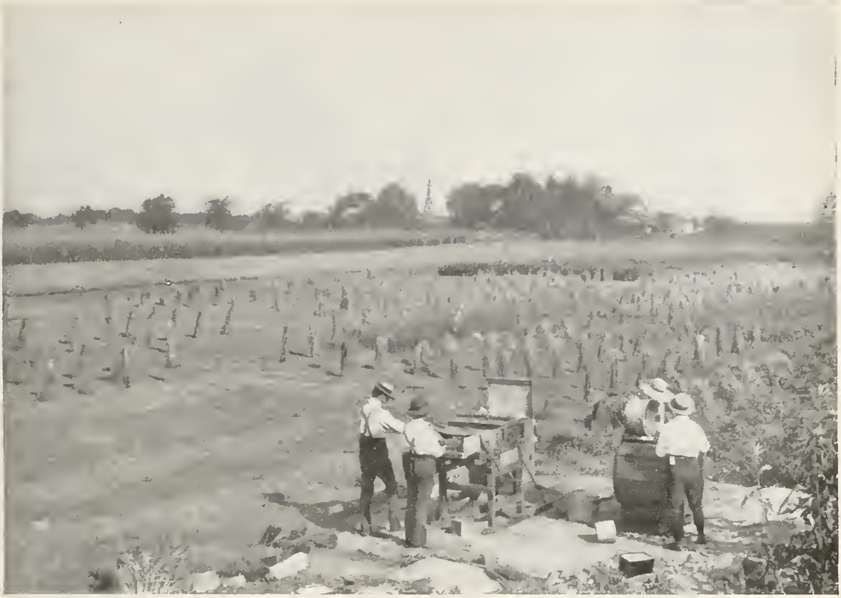


FIG. 1.—UNIVERSITY OF MINNESOTA—CENTGENER THRASHING MACHINE AND FANNING-MILL SEPARATOR IN USE IN THE FIELD CROP NURSERY.

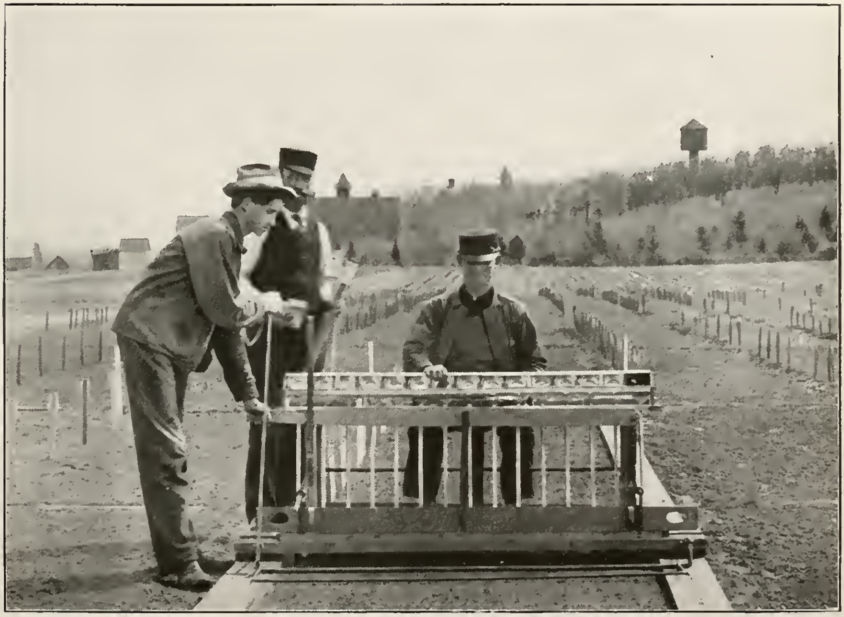


FIG. 2.—UNIVERSITY OF MINNESOTA—MACHINE FOR PLANTING GRAIN IN NURSERY BEDS.

The university farm contains 250 acres of land, of which about 150 acres are devoted to experiment station and college of agriculture work. The soil is a mixture of clay and sand, and is well adapted to the various uses to which it is put. On the portion of the farm used by the college and station there are many experiments in farm management, rotation of crops, treatment of pastures, improvement of crops by breeding (Pl. VII, fig. 2), etc. In the plant breeding experiments there are annually planted nearly 300,000 individual plants, including grains, clovers, root crops, etc., and for much of this work special machinery has been devised (fig. 7 and Pl. VIII, figs. 1 and 2).

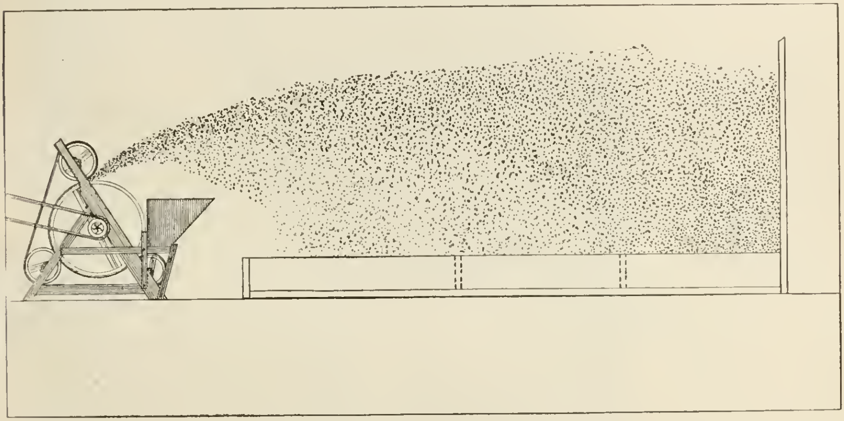


Fig. 7.—Centrifugal seed-grading machine.

Students who make a specialty of agronomy assist in these experiments. Farms in the vicinity serve as a basis for designing farm plans and working out problems in farm management.

THE UNIVERSITY OF NEBRASKA.

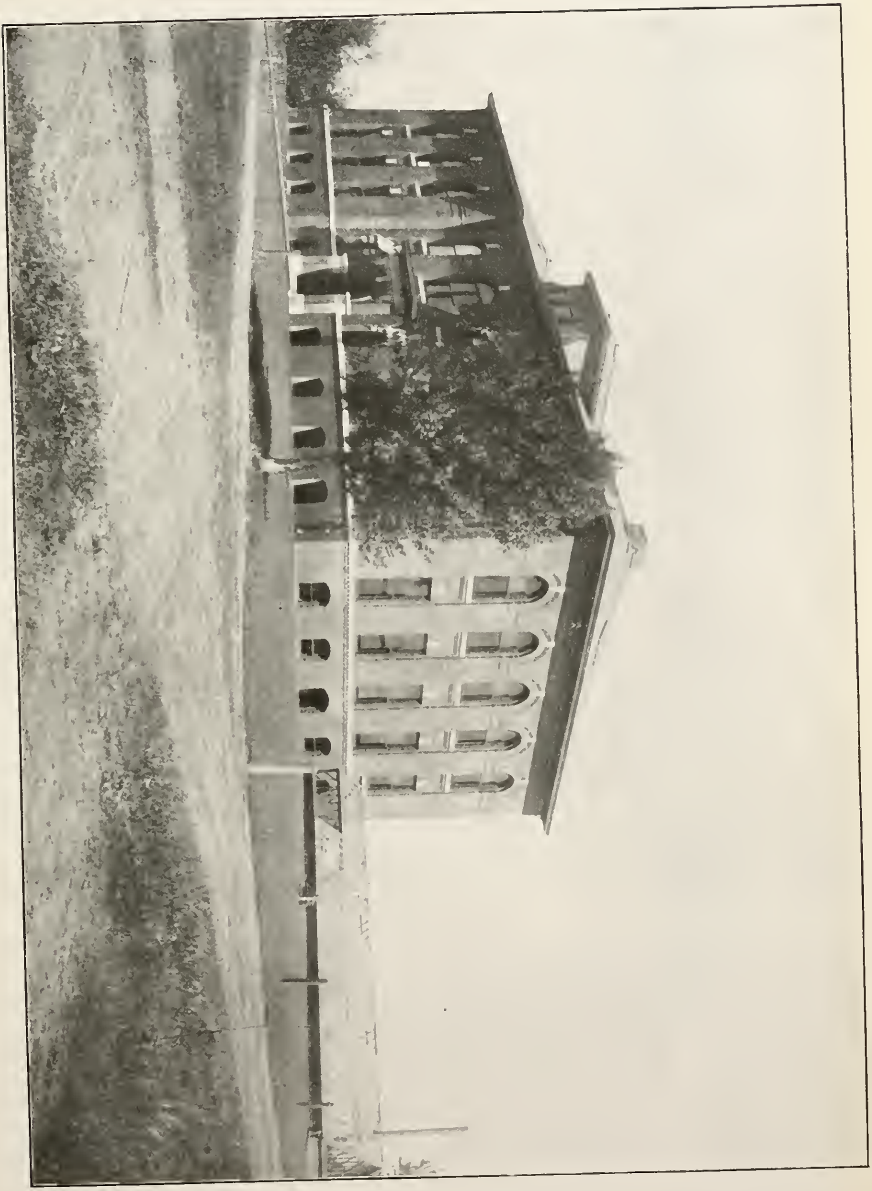
The industrial college of the University of Nebraska offers several four-year agricultural groups (courses) leading to the degree of bachelor of science—a technical group, a general group, and two special groups. The technical group is intended for graduates of the three-year course in the school of agriculture. "The studies in the general groups are arranged to meet the needs and requirements of those students whose primary object is a broad and general education." Those in the special groups are for students "fitting themselves to be instructors in agricultural subjects or to be experiment-station workers," and "have been planned and coordinated to enable students to direct their work so as to meet their individual needs and preferences." Candidates for admission to the general and special groups must present certificates from accredited schools, academies, or colleges, or must pass examinations (1) on the following required subjects: English, four years of language (ancient or modern or both), algebra through logarithms, plane and solid geometry, and elementary botany, chemistry, and physics; and (2) on a sufficient number of the following subjects for a total of 11 credits: Language, history, manual training, physical science, natural science, plane trigonometry, mechanical drawing, physiology and hygiene, physiography, civics, and political economy.

"All the courses in the first year of residence are prescribed, and form the common bases of both the general and the special groups offered." The courses included in this year and the number of hours per week for each course are mathematics 5, modern language 4, physics 3, English 2, chemistry 2, military drill 1. The work in chemistry includes "a careful study of the occurrence, methods of preparation, and properties of the common elements and their chief compounds." After the first year the courses are mostly elective. At least 40 per cent of the work of the last three years is taken in agriculture and chemistry or agriculture and botany, but "no student shall take or receive credit for more than forty hours' work in any department during his undergraduate course."

Agronomy at the University of Nebraska "includes on the instructional side the subjects of soils, field crops, farm management, and the care and use of farm machinery." The course in soils includes the following: The origin, deposition, and natural transportation of soils; physical and chemical constitution of soils and subsoils; influence of the size of soil grains on the rate of solution of plant food, drainage, aeration, water storage, capillarity, etc.; forms in which water exists in soils; movement of water in the soil; soil temperatures; evaporation of water from the soil; methods of soil treatment for conservation of soil moisture; the significance of a chemical analysis of soil; fixation of fertilizing materials; nitrification; availability of plant food; tillage, reasons for tillage, effect of drifting, effect of plowing wet or dry soil; subsoil plowing, water-holding power of loose and compact soils; disking, listing, etc.; the application of barnyard and green manures and commercial fertilizers. Given by the professor of agriculture.

This is followed by "field crops, their general composition and their relation to the air and soil; useful and essential ingredients of the ash of plants; functions of the ash constituents of plants and the formation of plant substance; functions of the roots, stems, and leaves of plants; the breeding of cereals; a treatment of each of the principal field crops, somewhat according to the following scheme: Characteristics, varieties, vitality, climate, soil, manures, tillage, seeding, cultivation, harvesting, preservation, position in rotation, uses. Given by the professor of agriculture."

Following these two courses is a laboratory course in the "Properties of soils," continuing throughout the year and given by the professor of agriculture and the instructor in agriculture.



UNIVERSITY OF NEBRASKA—AGRICULTURAL BUILDING.

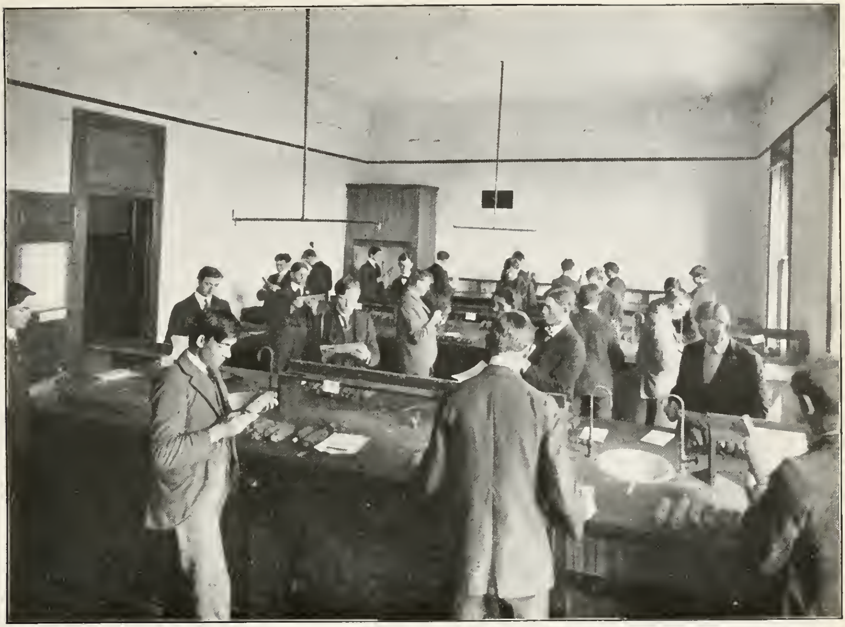


FIG. 1.—UNIVERSITY OF NEBRASKA—FIELD CROPS LABORATORY, STUDENTS JUDGING SEED CORN.

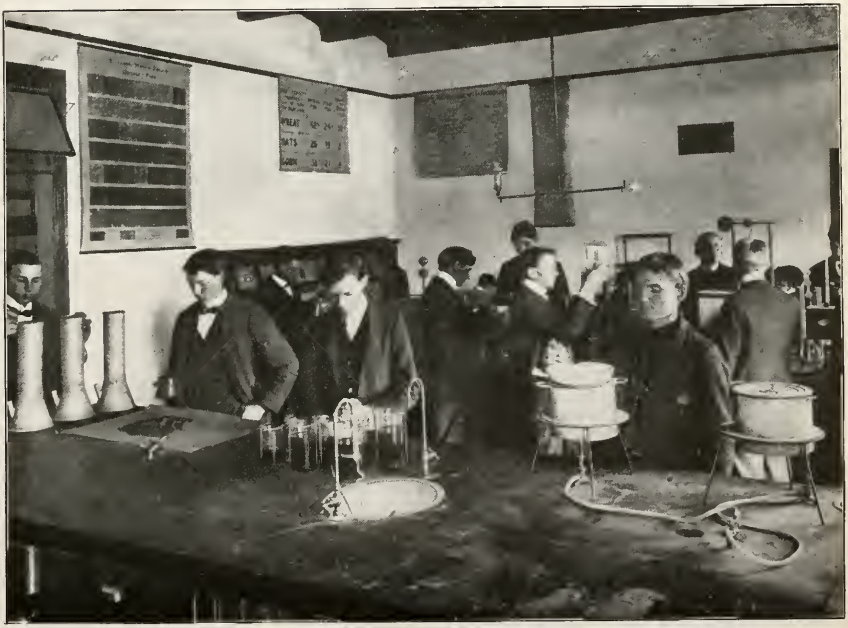


FIG. 2.—UNIVERSITY OF NEBRASKA—SOILS LABORATORY.

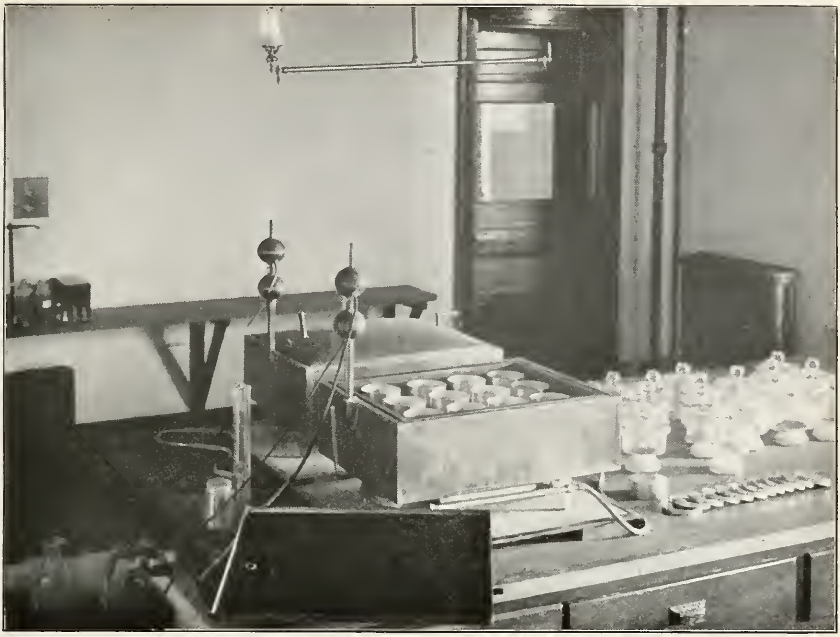


FIG. 1.—UNIVERSITY OF NEBRASKA—APPARATUS FOR MAKING DETERMINATIONS OF SOIL MOISTURE.

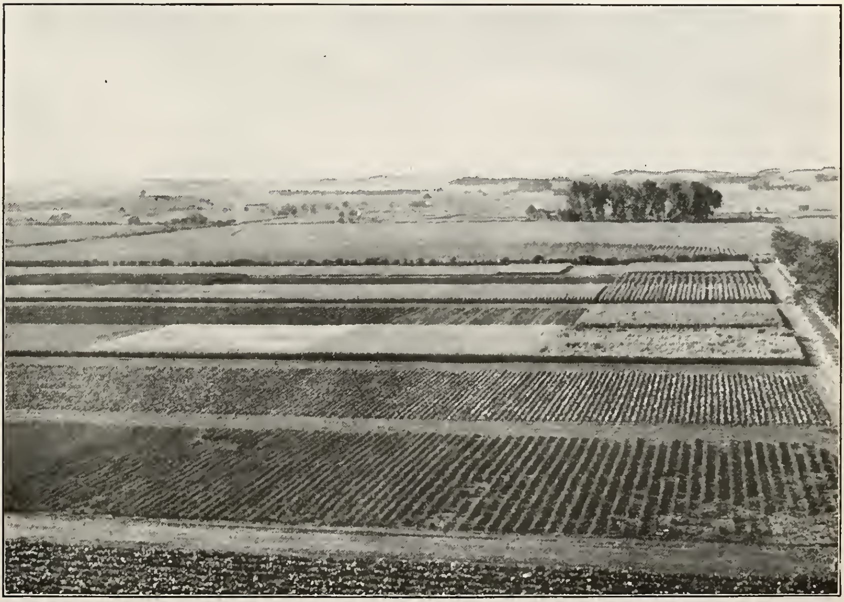


FIG 2.—UNIVERSITY OF NEBRASKA—EXPERIMENT PLATS.

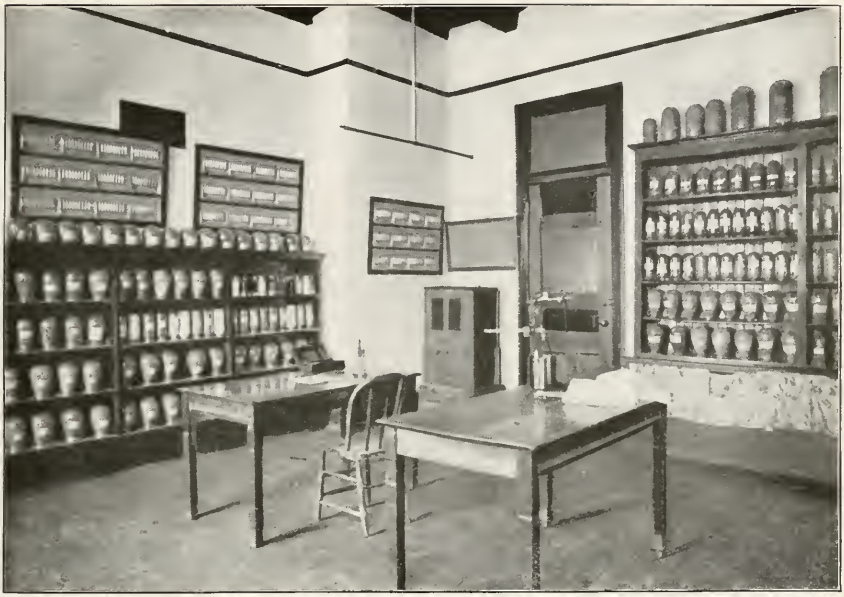


FIG. 1.—UNIVERSITY OF NEBRASKA—SEED LABORATORY.

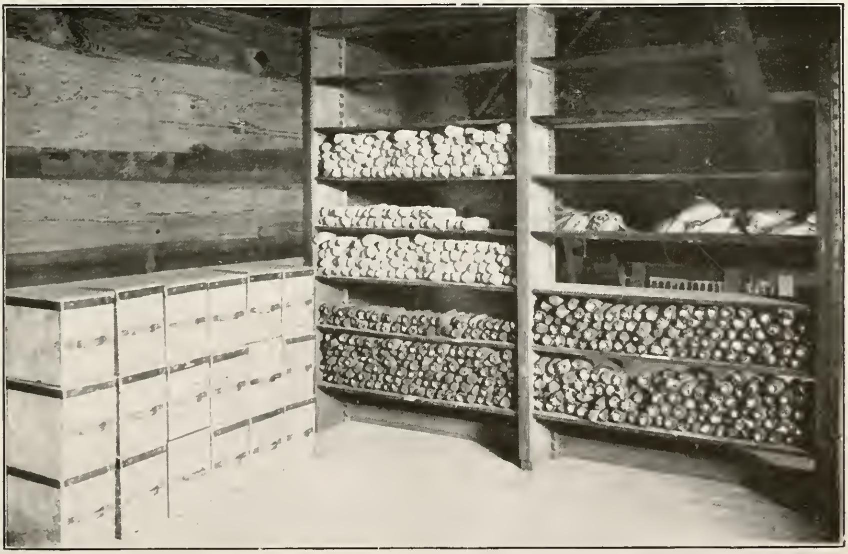


FIG. 2.—UNIVERSITY OF NEBRASKA—CORNER IN THE SEED STOREROOM.

Elective courses are offered as follows:

“Methods of investigation with soils. A study in detail of reported experiments, the object being to familiarize the student with the methods of scientific investigation in the subject under discussion.

“Methods of investigation with field crops. Conducted similarly to the above.

“Plant food in the soil; a series of pot experiments.

“Production and movement of crops as affecting prices.

“Sugar-beet culture. History of the culture of the sugar beet. Effect upon general agriculture of sugar-beet culture. Varieties of the sugar beet. Types. Composition and structure of the beet plant. Soils and climatic conditions adapted to raising sugar beets. Preparation of the soil. Planting the seed. Cultivation. Harvesting. Siloing. Seed production; breeding, establishing of strain. Position of the beet crop in the system of crop rotation.

“The laboratory work [in soils] consists of the following demonstrations: Determination of specific gravity of soils; determination of the volume weight of soils; power of loose soils to retain moisture; the power of compact soils to retain moisture; rate of percolation of water through soils; rate of percolation of air through soils; effect of mulches on evaporation of water from soils; behavior of the soil toward gases; capillary attraction of the soil; the power of soils to fix ammonia.”

Instruction for students in these courses is by means of lectures and laboratory practice, using books of reference throughout almost the entire course. In the study of field crops the experiment station publications are used very freely. Students fitting themselves to be instructors in agricultural subjects or to be experiment station workers are given every opportunity to study the methods of agricultural investigations at the agricultural experiment station farm.

Class rooms and laboratories used for instruction in agronomy are in the general agricultural building (Pl. IX). One class room, 33 by 20 feet (Pl. X, fig. 1), contains specimens of plants, seeds, etc., used for purposes of instruction in field crops. One laboratory, 33 by 20 feet (Pl. X, fig. 2), is used for demonstrations of various properties of soils.

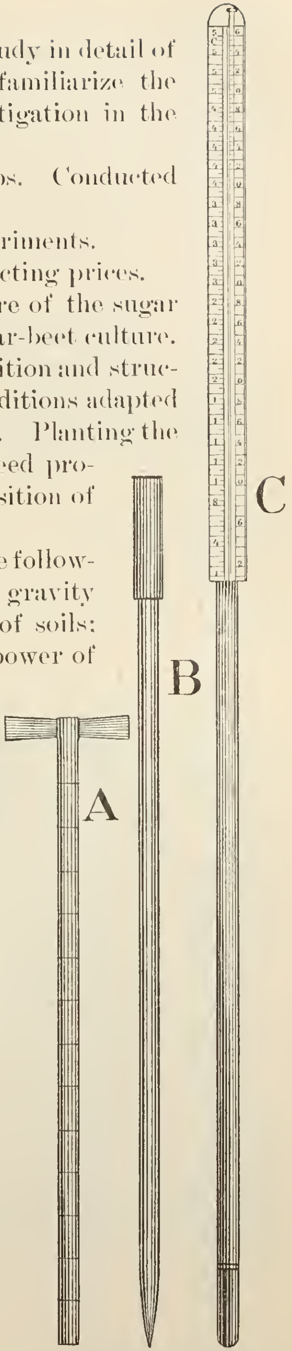


Fig. 8.—Movable soil thermometer: A, hollow steel tube, ½ inch internal diameter, 15 inches long; B, solid steel plunger, 19 inches long, which closely fits the tube A; C, long stem (18 inches) thermometer which closely fits the tube A.

This laboratory is provided with desks, water, gas, etc., and may be considered a well-equipped laboratory. The desks are $3\frac{1}{4}$ feet high and 4 feet wide, with drawers and cupboards on both sides and water and gas cocks in the center. The apparatus is designed to record soil temperatures (fig. 8), to take samples of soils (fig. 9), to determine soil moisture (Pl. XI, fig. 1), and to test a number of properties of different soils, for instance, the water-holding power of loose and compact soils, the rate of percolation of air through soils, and certain other physical properties, some of the apparatus for which was designed by Professor Gibbs, formerly of the Ohio State University.

About 50 acres of land are used for purposes of instruction, although other land used for experimentation may also be considered as a part of the instructional equipment (Pl. XI, fig. 2). Forty acres are divided into subfields of exactly 5 acres each. These fields are not fenced, but are divided by roadways, the land occupied by which is not a part of the 5-acre tracts.

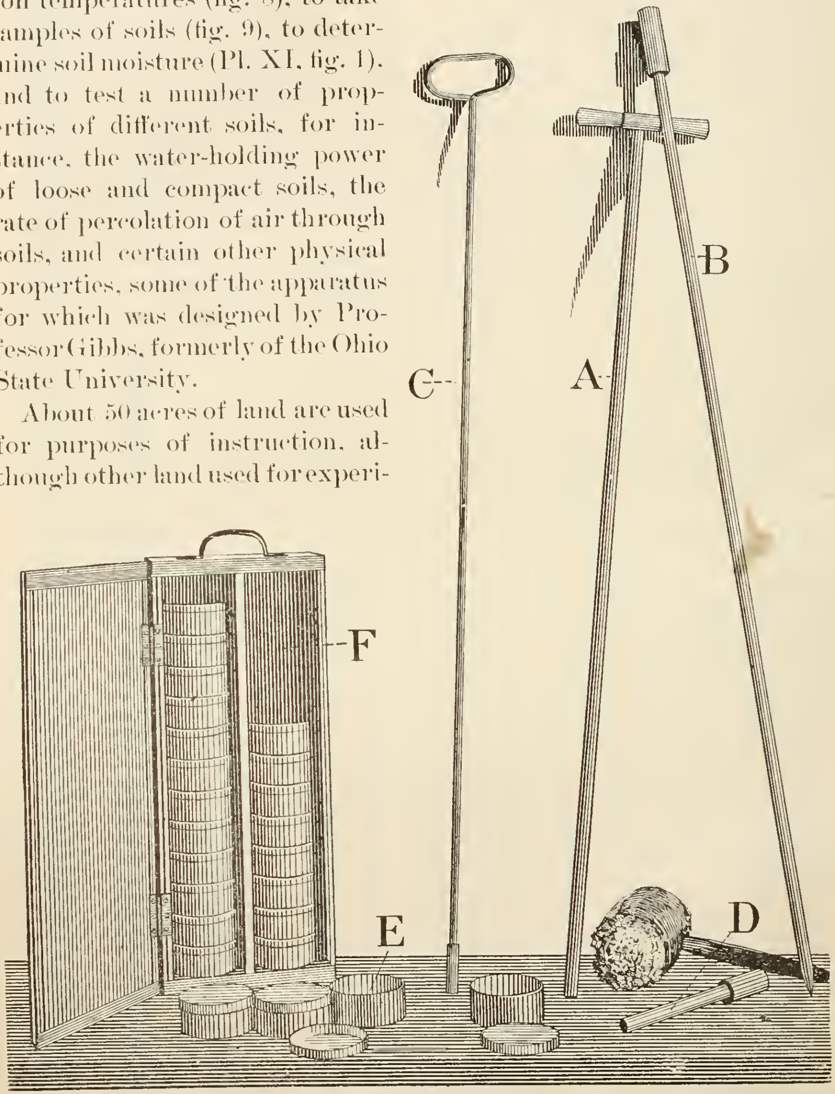


FIG. 9.—Soil-sampling apparatus: A, hollow steel sampling tube, $\frac{7}{8}$ inch internal diameter, 45 inches long, marked every 3 inches; B, solid steel rod, $46\frac{1}{2}$ inches long, which closely fits A; C, ejector; D, driving head for sampling tube; E, aluminum cans for soil samples; F, case for sample cans.

The roadways are 1 rod wide. Four of the subfields are severally in rotations, intended to demonstrate the effect of manuring and of periodically seeding to grass. For instance, subfields C and H are each year planted to the same crops and the same character of manure applied in equal quantities, the only difference being that at certain intervals subfield H is allowed to lie in grass for a period of years, while subfield C is cropped continuously. The following is the rotation:

	Subfield C.	Subfield H.
1898	Corn (manured)	*Bromus inermis.*
1899	Corn	*Bromus inermis.*
1900	Oats	*Bromus inermis.*
1901	Winter wheat	*Bromus inermis.*
1902	Corn (manured in winter)	Corn (top-dressing of manure before plowing up *Bromus inermis*).
1903	Oats	Oats.
1904	Winter wheat	Winter wheat.
1905	Corn (manured in winter)	Corn (manured in winter).

Subfields D and I are in similar rotations, except that subfield D does not receive any manure and that the crops grown on these fields are not the same as those on the other two subfields during the same year. The remainder of the subfields are used for growing new and not generally grown crops or for particularly good varieties or strains of varieties of common crops. In another field are 10 acres divided into plats of one-fifth acre, and each of these is planted to a particular perennial forage plant or combination of such plants. These are mostly grasses and clovers. They serve as an object lesson in profitable seeding to pastures and meadows in this region. Hurdles of special size are provided for fencing these, so that any one of them may be pastured when desired. In this manner the pasturage value is demonstrated. There is also a field of about 10 acres divided into experiment plats of one-tenth acre each. These, although primarily for experimentation, are also of value for purposes of instruction.

For instruction in implements and machinery, there are walking, riding, and disk plows; breaking plows; disk, spike, acme, and spring-tooth harrows; subsurface packer; roller; subsoilers; press drills; lister; corn planter; mowers; rake; hay loader; hay tedder; binder; thrashing machine, etc. There are, for instruction in soils, samples of soils from nearly a hundred different localities in the State. These have been analyzed mechanically and the original soil and its constituent parts arranged in small vials on a card showing the percentage of the various sized particles. There is a collection of about 90 of the native grasses in the State and some 200 specimens of grains (Pl. XII, figs. 1 and 2).

The college classes in soils use Snyder's Chemistry of Soils and Fertilizers, but the course is given largely by means of lectures. In field crops frequent use is made of Farmers' Bulletins and State agricultural society reports, and of Morrow and Hunt's Soils and Crops of the Farm. The principal books of reference for classes in soils are Le Conte's Elements of Geology, Warington's Chemical and Physical Properties of Soils, Wahnschaffe's Scientific Examination of Soils, Johnson's How Crops Feed, Storer's Agriculture, and Roberts's Fertility of the Land; for classes in field crops, the publications of the various experiment stations and of the United States Department of Agriculture.

The agricultural library contains complete or nearly complete sets of the Annals of Agriculture, Journal of the Royal Agricultural Society of England, Transactions of the Highland and Agricultural Society of Scotland, Quarterly Journal of Agriculture, Journal of Agriculture, Journal für Landwirtschaft, Centralblatt für Agriculturchemie, Forschungen auf dem Gebiete der Agricultur-Physik, an almost complete set of the publications of the various State experiment stations, and a fairly complete set of the publications of the United States Department of Agriculture. There is also a fairly complete collection of text-books and other books dealing with agriculture in a general or special way, besides files of the more important agricultural newspapers. Altogether, in that section of the library pertaining to agronomy there are upward of 1,500 volumes.

OHIO STATE UNIVERSITY.

The four-year course in agriculture leading to the degree of bachelor of science in agriculture is given in the College of Agriculture and Domestic Science of the Ohio State University. This course is designed not only to make specially trained agriculturists, but also educated men. The course presupposes that a young man has had a high school training or its equivalent, and that he has had the training in farm matters that necessarily comes to a young man who has lived on a farm. It supplements this training, but does not displace it. About one-third of the time of the student during the four years is or may be devoted to language (English or foreign), history, and economics; about one-third to pure science, and one-third to technical or professional training. Electives in the senior year allow for some variation in this regard.

Applicants for admission to this course must be at least 16 years of age and have graduated at a State normal school, or approved high or preparatory school, or have passed examinations in the following subjects: English grammar, composition and rhetoric, English classics; arithmetic, algebra, plane geometry; descriptive and physical geography, elementary botany, and physics; civil government or general history; and Latin (grammar and four books of Cæsar), or French (grammar and simple reading and translating), or German (grammar and reading, not less than 300 pages).

The course in agronomy is given during the third or junior year of the college course and is preceded by instruction in agricultural chemistry (during the first and second years), physiological and economic botany and vegetable pathology (during the first year), and horticulture (during the second year).

In chemistry the course includes lectures and laboratory work on the principles of chemistry and chemical nomenclature, organic chemistry, and the application of chemistry to agriculture. The latter is given during the third term of the first year and includes the following topics: Ingredients of plants, organic and inorganic, essential and non-essential; sources of plant food, air, and soil; nature of soil, mechanical portion, nutritive portion, assimilable, and reserve plant food; soil exhaustion and amelioration; barnyard manure, its sources, composition, and preservation; commercial fertilizers, their rational use and methods of determining the needs of soils. In the second year there are lectures and laboratory work on the industries related to agriculture (e. g., manufacture of sugar, starch, vinegar, and liquors); and the analysis of fertilizers, feeding stuffs, dairy products, sugar and sugar producing plants, fruits and vegetables, water, soils, oils, fats, grains, etc. The lecture rooms and laboratories are thoroughly equipped with apparatus and chemicals for the use of instructors and students.

The course in botany includes elementary, physiological, and economic botany, and vegetable pathology, with lectures and recitations three times a week and laboratory and field work twice a week. In economic botany the student receives instruction and practice in handling the microscope and has the opportunity of learning much of the important modern methods in technique. The main part of the course in vegetable pathology is devoted to a study of the parasitic fungi most destructive to cultivated plants, and the means of their prevention forms the last part of the course. Instruction in botany is given in the botanical building which contains a large lecture room, museum, herbarium, three laboratory rooms, dark room, drying room, storeroom, and offices. The lecture room will, the coming year, contain a stereopticon furnished with electric light; a large number of charts, many of them colored lithographic photographs and mounted illustrative specimens are the principal appliances for daily class work. In this room are placed fifteen of the more important popular journals of botany for the use of students. The botanical books in the university library, a valuable and growing collection, are largely used for reference in connection with the several courses. The museum contains a large amount of illustrative material, the native medicinal plants and the collection of Ohio woods being very complete. The State herbarium consists of between 12,000 and 15,000 sheets of Ohio plants. The general herbarium is about the same size. Professor Kellerman's private herbarium of 20,000 specimens, mostly parasitic fungi, is also used by the department. The large laboratory is well equipped with dissecting and compound microscopes; also the usual appliances for doing both elementary and advanced histological work. One of the small laboratories is devoted to experimental work in vegetable physiology and the other to systematic botany. The greenhouse attached to the botanical building is an important adjunct to the department. There are four sections containing a total of nearly 3,000 feet of glass. It contains a large number of illustrative plants, perhaps 3,000 specimens, representing the principal plant families and belonging to several hundred species. The greenhouse furnishes much fresh material for laboratory use. It is also used as a laboratory to carry on special work when growing plants are used.

The courses in agronomy are given by the professor of agriculture and the instructor in agronomy and include two elementary courses during the second and third terms of the junior year and two advanced elective courses during the first and second terms of the senior year. The courses in the order in which they must be taken are as follows:

Elementary course in soils.—Lectures and recitations three times a week upon the origin, formation, kinds, and physical properties of soils and their improvement by cultivation, fertilization, drainage, and irrigation. Practicum once a week in laboratory, testing physical properties of several soils; determining the relation of soils to heat, moisture, air, and fertilizers, and making mechanical analyses. For a detailed description of the laboratory exercises in this course, see Exhibit No. 7, page 59.

Elementary course in farm crops.—Lectures and recitations three times a week upon the history, production, marketing, cultivation, and harvesting of farm crops. For a list of examination questions indicating the scope of this work, see Exhibit No. 9, page 70. Practicum once a week with growing and dried specimens of farm crops, including grasses, clovers, and other forage crops. A list of laboratory or field practicums in this course is given in Exhibit No. 10, page 71.

Advanced course in soils.—Lectures and recitations once a week on the physical properties of soils; the relation of soils to heat, air, and moisture; the effect of fertilizers on soil structure and fertility; consideration of practical methods of tillage as affecting crop producing power of the soil. Laboratory and field experiments during two two-hour periods each week. A detailed schedule of laboratory work in this course is given in Exhibit No. 8, page 69.

Advanced course in farm crops.—Lectures and recitations once a week on (*a*) the effect of climate, soil, and markets on the distribution and adaptation of farm crops in the United States; (*b*) the best method of crop production, including a careful study of the details of field

OHIO STATE UNIVERSITY—TOWNSHEND HALL.

experimentation as set forth in experiment station bulletins and reports and the publications of the United States Department of Agriculture; (*c*) the consumption of farm crops. Practicums twice a week.

Instruction in these courses is given largely by means of lectures, but frequent use is made of such text-books as The Soil and the Physics of Agriculture, by King; and Soils and Crops of the Farm, by Morrow and Hunt; and of bulletins, monographs, and reports issued by the experiment stations and Departments of the United States Government.

Instruction in agronomy, as in other branches of agriculture, is given in the university building known as Townshend Hall, which was completed in 1898 at a cost of $100,000.

Townshend Hall (Pl. XIII) is 260 feet long, and varies in width from 64 to 78 feet. It contains two stories and a basement which is 14 feet high, making the building practically three stories high. The walls above the basement line are of gray pressed brick. The basement walls and the front entrance are of Bedford, Ind., Oolotic limestone, and the trimmings are of terra cotta of the same color as the brick. The roof is of dark-red tile. The building is of slow-burning construction throughout, with painted interior brick walls, exposed beams, maple floors, and hard pine finish. The lecture rooms and laboratory for the course in agronomy are on the first floor of this building.

The soil physics laboratory is supplied with apparatus for studying the specific gravity of soils; volume weight of soils; power of loose soil to retain moisture; power of compact soil to retain moisture; rate of flow of air through soils; rate of percolation of water through soils; effect of mulches on evaporation of water from soils; effect of cultivation on evaporation of water from soils; power of dry soil to absorb moisture from the air; and the capillary rise of water through soils. Mechanical analyses are also made of typical soils.

In the study of soils, the large glass house with its equipment of railroad tracks, trucks, and pots affords opportunity for the student to test the adaptability of crops to various soils; the fertilizer requirements of soils and to experiment on various other problems of crop growth.

In the study of crops, large use is made of the collection of dried specimens of grasses, grains, and seeds. The grass garden contains about 25 varieties of grasses and clovers growing side by side where comparisons may be made as to the value of each for pasture, meadow, and grass. The farm is visited frequently by students who make observations and studies of the practical methods there employed in the growing of crops.

Exhibit No. 7.

LABORATORY WORK IN THE ELEMENTARY COURSE IN SOILS.

Experiments are arranged with reference to the number of laboratory periods in the term, and since there are ten to twelve periods, 12 experiments have been planned which are described on the following pages. The experiments are designed with special reference to the practical demonstration of some of the important principles underlying soil physics, and to supplement class-room teaching with actual work with the soil itself.

The following soils used in the experiments are typical agricultural soils selected on the Ohio State University farm with reference to their differences in texture and crop producing power:

No. 1. Muck soil. Selected from a very fertile cornfield.
No. 2. First bottom alluvial loam. Very fertile.
No. 3. Second bottom sandy loam with considerable clay.
No. 4. Fine sand (0.25 millimeter to 0.1 millimeter in diameter).
No. 5. Coarse sand (0.5 millimeter to 0.25 millimeter in diameter).

The soils are brought from the fields and air-dried in the laboratory. Numbers 1 to 3 are sifted through a 2-millimeter sieve having circular holes, and numbers 4 and 5 through finer sieves. The soils are then placed in numbered bins in the laboratory.

The following is a list of the laboratory experiments with descriptions and illustrations of each:

Experiment No. 1.

DETERMINATION OF SPECIFIC GRAVITY OF SOILS.

This experiment shows weights of the various soils as compared with the weights of equal volumes of water. The specific gravity of most soils is about 2.5—that is, soil calculated free of air space weighs 2.5 times as much as an equal volume of water. The more organic matter a soil contains the less its specific gravity. In general, the specific gravity of a soil decreases inversely as its content of organic matter. Specific gravity must not be confused with apparent specific gravity, which will be explained in experiment No. 2.

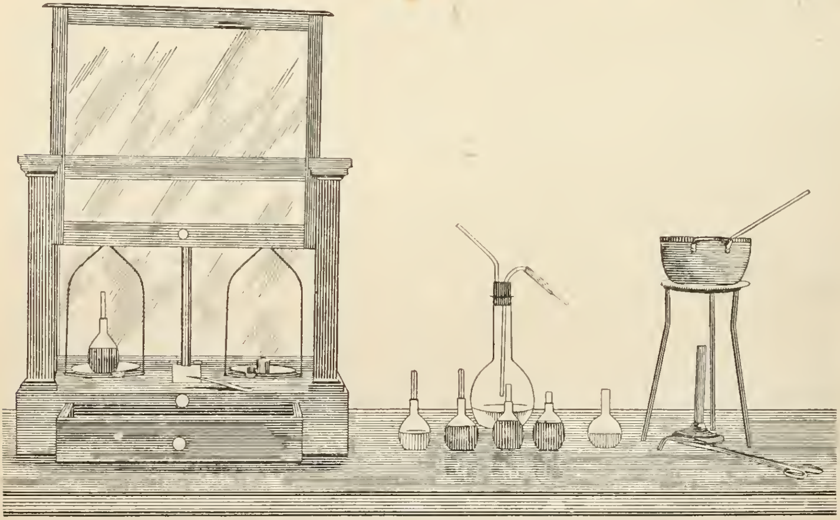


FIG. 10.—Apparatus for determining specific gravity of soils.

With a flask of 50 cubic centimeters capacity and provided with a ground-glass stopper, drawn out to an open capillary tube (fig. 10), determine specific gravity of four soils which will be provided—Nos. 1, 2, 3, and 4.

Fill flask with distilled water so that no air bubbles appear after the ground-glass stopper is inserted. Note temperature of water in flask. Wipe flask dry and weigh.

Pour out about one-half of the water in the flask and put in a weighed quantity (10 grams) of the soil, which has been previously dried at 110° C. for twenty-four hours. Place the flask in a shallow water bath and boil for two minutes in order to drive out the soil air. Fill the flask with distilled water and bring to the same temperature at which the previous weight was taken. Weigh. (See that flask is full when weight is taken.)

Calculation.—Add weight of soil used to weight of flask filled with water and deduct therefrom weight of flask filled with water and soil. The difference expresses the weight of a volume of water equal to the quantity of soil used.

The specific gravity is found by dividing the weight of the soil taken by the weight of the water it has displaced.

Experiment No. 2.

DETERMINATION OF THE VOLUME WEIGHT, APPARENT SPECIFIC GRAVITY, AND POROSITY OF SOILS.

Determine the volume weight of four soils, Nos. 1, 2, 3, and 4. Weigh the empty tubes (fig. 11) carefully. Use the soil direct from the bins and pour into the tube the measure level full. Then place the tube in the compacting machine (fig. 12) and allow the weight to fall six times from the 12-inch mark. Pour in another measure of soil and repeat. Continue this until the tube is filled to the mark near the top. Weigh. Determine at the same time with a special sample the hygroscopic water which escapes at 110° C. Also determine the number of cubic inches, or centimeters, occupied by the soil in each tube.

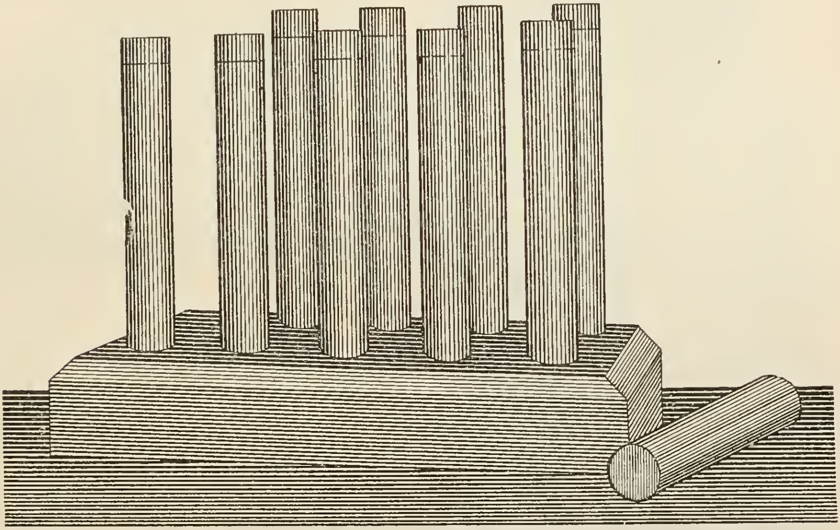


FIG. 11.—Determination of volume weight, apparent specific gravity, and porosity of soils.

Calculations.—Subtract the weight of the empty tube plus the weight of hygroscopic water in the soil used from the weight of the filled tube. This will be the weight of the given volume of soil. The volume weight of a cubic centimeter of soil should then be calculated.

By dividing the volume weight of the soil with the weight of the same volume of water, the apparent specific gravity of the soil is obtained.

By dividing this apparent specific gravity with the real specific gravity of the soil obtained in experiment No. 1, and substracting from 100, the remainder expresses the per cent of porosity of the soil, i. e., the space which, in the dry soil, is occupied by air.

The volume weight of a soil varies with the amount of packing. A freshly plowed soil is much lighter per cubic foot than the same soil packed by rains or by tramping. In other words, soil has an apparent and a real specific gravity. Average field soils in good tilth have an apparent specific gravity of about 1.2, and when entirely free from air, a real specific gravity of about 2.5.

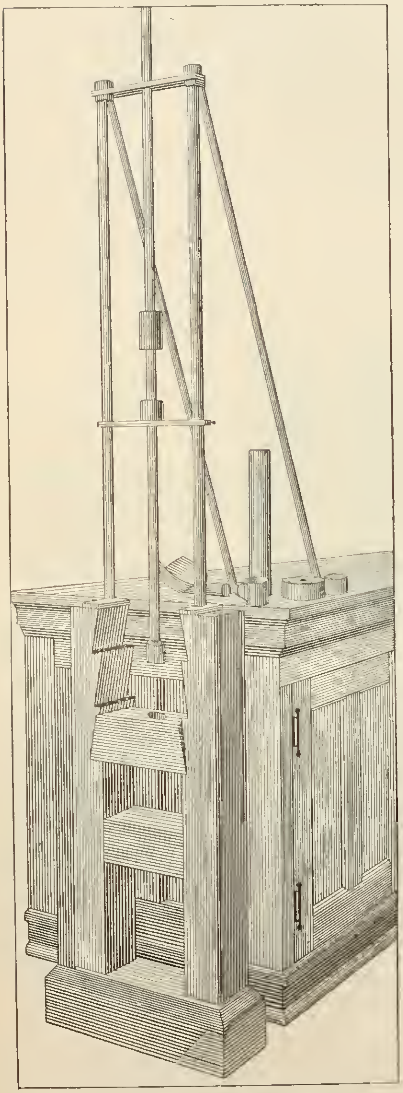


FIG. 12.—Soil-compacting machine.

The compacting machine referred to above was designed to pack all the soils into the tubes uniformly and thus eliminate, in a large degree, the error due to unequal packing in different tubes when making comparisons of apparent specific gravity of different soils. The machine does not do the work with absolute exactness, but seems to be a decided improvement over the uncertain method of filling by hand, which at best gives very unsatisfactory results.

Experiment No. 3.

THE POWER OF LOOSE SOILS TO RETAIN MOISTURE.

Use soils Nos. 2, 3, 4, and 5 in this experiment. Place disks of damp cheese cloth in the bottom of the tubes (fig. 13) and then weigh the tubes carefully on the torsion balance. Fill the tubes up to the mark, 1 inch from the top, by pouring the soil in gently, leaving the soil in the tubes in a very loose condition, with much air space throughout the mass. Weigh the filled tubes. Place the filled tubes in the empty galvanized iron box. Pour water in the box until the water level almost reaches the tops of the tubes, thus allowing the water to percolate up through the soils. When the water level in the tubes comes up to the level of the water in the box remove the tubes and place them in the frame, where the water is allowed to percolate out of them. Glass plates should be placed over the tops of the tubes to prevent evaporation. The tubes should be weighed from day to day until the minimum weight is reached—until percolation ceases.

The difference in weight between the tubes filled with dry soil and the wet soil will be the amount of water retained by the loose soil. In order to get the total water content of the wet soil, it is necessary to add to this the weight of hygroscopic water which the dry soil contained. The hygroscopic water of the dry soil should be determined with a special sample taken at the time the tubes are filled.

Calculate the total number of pounds of water retained per cubic foot of dry soil and also the number of surface inches of water it represents.

This experiment illustrates the power of different types of loose soil to retain water. One of the advantages of cultivating soil is to make it loose in structure so that rain will be absorbed and retained more thoroughly than would be the case if the soil were uncultivated. Study results from this experiment in connection with those of experiment No. 4 for compact soil.

Experiment No. 4.

THE POWER OF COMPACT SOILS TO RETAIN MOISTURE.

Use soils Nos. 2, 3, 4, and 5 in this experiment. Place disks of moist cheese cloth in the bottom of the tubes (fig. 13). Weigh and then fill within 1 inch of the top in the following mannner: Pour in 1 measure of soil. Place cylinder in compacting machine and drop weight six times from the 12-inch mark. Pour in another measure and repeat. Continue this until cylinder is filled within 1 inch of the top.

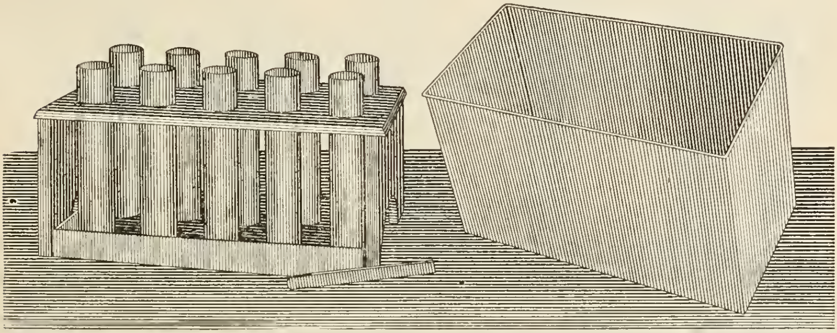


FIG. 13.—Determining the power of soils to retain moisture.

Place the filled tubes in the empty galvanized iron box. Pour water in the box until the water level almost reaches the tops of the tubes, thus allowing the water to percolate up through the soils. When the water level in the tubes comes up to the level of the water in the box remove the tubes and place them in the frame where the water is allowed to percolate out of them. Glass plates should be placed over the tops of the tubes to prevent evaporation. The tubes should be weighed from day to day until the minimum weight is reached—until percolation ceases.

The difference in weight between the tubes filled with dry soil and the wet soil will be the amount of water retained by the compact soil. In order to get the total water content of the wet soil it will be necessary to add to this the weight of hygroscopic water which the dry soil contained. The hygroscopic water of the dry soil should be determined with a special sample at the time the tubes are filled.

Calculate the total number of pounds of water retained per cubic foot of dry soil and also the number of surface inches of water it represents.

This experiment illustrates the power of different types of compact soil to retain water.

The results of this experiment should be studied in connection with those of experiment No. 3.

Experiment No. 5.

RATE OF PERCOLATION OF WATER THROUGH SOILS.

The series of tubes (fig. 14) having been filled within 1 inch of the overflow pipes with soils Nos. 1, 2, 3, 4, and 5, the compacting machine is used.

After each measure of soil was put in the weight is dropped twice from the 6-inch mark. The surface of the soil in each tube is covered with 1 inch of coarse gravel to prevent the soil being disturbed by flowing water.

See that all tubes are connected by rubber tubing and the extreme ends of small tubes corked.

Pour in distilled water gently and keep the cylinders almost level full. After the flow into the glass flasks has become uniform, note the number of cubic centimeters which flow through in half an hour. Determine this by measuring in a graduated cylinder.

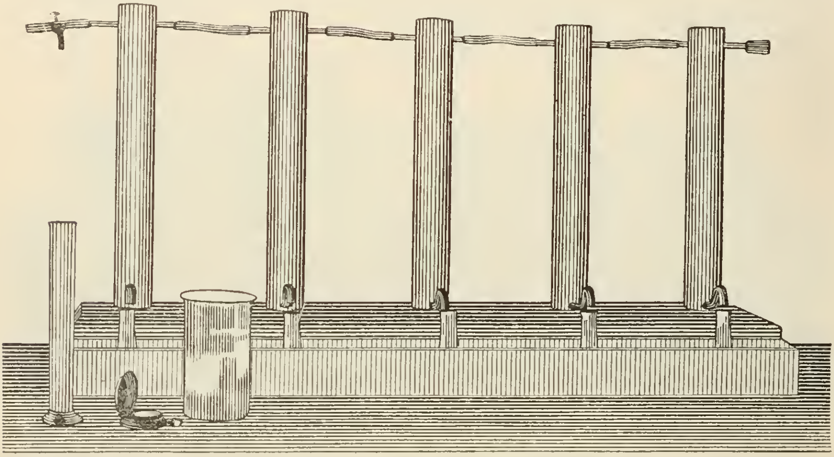


FIG. 14.—Rate of percolation of water through soils.

The character of soils used may be examined in the boxes in the laboratory. The tubes are numbered to correspond with the soil numbers.

This experiment brings out the differences between soils in regard to the rate of percolation of water through them. Other things equal, it is desirable that a soil should allow water to pass through slowly, holding moisture the greatest length of time within the reach of crop roots.

Experiment No. 6.

RATE OF FLOW OF AIR THROUGH SOILS.

Soils Nos. 1, 2, 3, 4, and 5 are used in this experiment. The cylinder numbers correspond with the soil numbers.

The compacting machine was used in filling the cylinders (fig. 15). After each measure of soil, the weight was dropped three times from the 12-inch mark.

Open the cock on the copper cylinder and detach the hook holding the weights. Allow the copper cylinder to sink by its own weight. Attach the rubber tube to soil tube No. 1. Attach the weight hook and note the number of degrees passed by the pointer in 10 minutes or a longer time, if it be necessary in case of the fine-grained soils. Record the weight for each of the five soils, calculating the weight per hour.

This experiment has a direct practical bearing on the question of soil ventilation. Soil air is essential to the life of nitrifying and other bacteria which develop fertility. Other things equal, the more readily soil will allow air to circulate through it, the more favorable conditions will be for the formation of plant food.

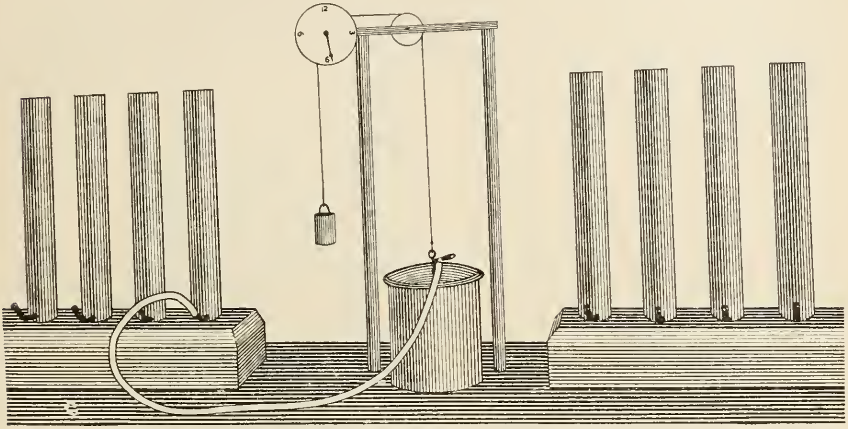


FIG. 15.—Apparatus to determine the rate of flow of air through soils.

Experiment No. 7.

EFFECT OF MULCHES ON EVAPORATION OF WATER FROM SOILS.

The cylinders (fig. 16) are 18 inches deep by 4 inches in diameter, and are filled with first bottom soil from the Ohio State University farm. The compacting machine was used in filling the cylinders to insure comparatively uniform compactness of soil in all cylinders.

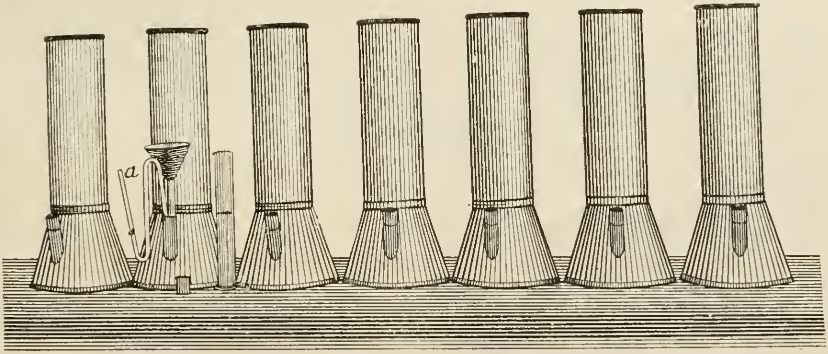


FIG. 16.—Soil tubes for showing the effect of mulches on evaporation of water from soils.

No. 1. Not mulched.
No. 2. Not mulched.
No. 3. Surface cultivated 2 inches deep. (Soil mulch).
No. 4. Surface cultivated 2 inches deep. (Soil mulch).
No. 5. Mulched with 2 inches of coarse gravel.
No. 6. Mulched with 2 inches of fine sand.
No. 7. Mulched with 2 inches of sawdust.
No. 8. Mulched with 2 inches of cut straw.

No. 9. Not mulched. (Placed in draft).

No. 10. Not mulched. (Placed in draft).

Fill the cylinders to the same level with distilled water every twenty-four hours for one week and keep a careful record of the amount of water used each day. The "S" glass tube (*a*, fig. 16) will be used to determine the exact level to which the tubes should be filled.

The cylinder which evaporated the least water during the period of observation should be the one having the most effective mulch.

In recording results show the amount of water put in each cylinder daily, and also the total amount for each cylinder for the entire run of the experiment.

Experiment No. 8.

THE POWER OF AIR-DRY SOIL TO ABSORB MOISTURE FROM THE AIR.

Use soils Nos. 1, 2, 3, and 4 in this experiment. Place 400 grams of air-dry soil from the bin in a shallow zinc tray (fig. 17), spreading it out as uniformly as possible.

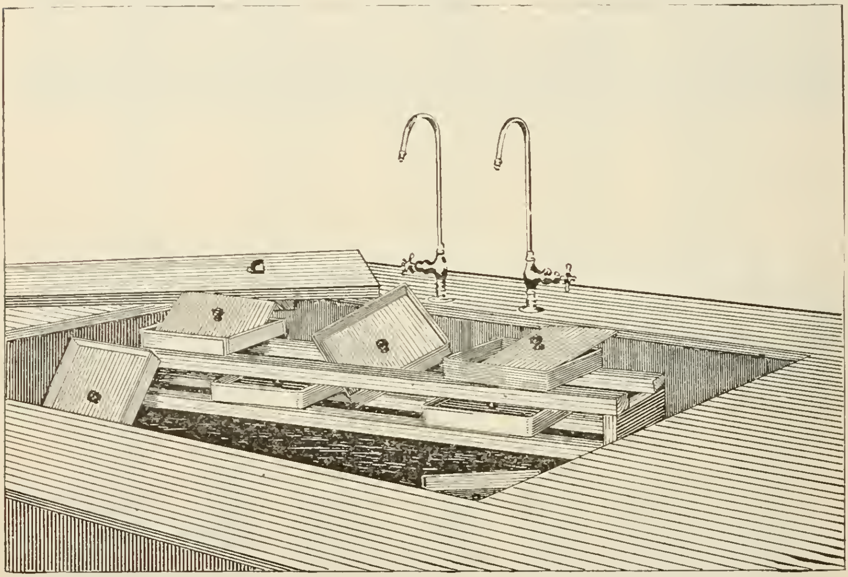


FIG. 17.—Determining the power of air-dry soils to absorb moisture from the air.

After weighing the tray (lid on) with the soil, place an empty weighed box, together with the others (lids off), upon a shelf in the pneumatic trough. Place a thermometer in the trough and at each weighing read the temperature. Weigh each box (lid on) every twenty-four hours and deduct the increase in weight of the empty box from the increase in weight of each of the other boxes. Repeat the weighings every twenty-four hours until with the same conditions of temperature an approximately constant weight is obtained. The moisture retained is calculated for 100 grams of the soil dried at 110° C. Add to this increased weight per 100 grams of air-dry soil the weight of hygroscopic water contained in 100 grams of the air-dry soil. This will give the total amount of water taken from the air by 100 grams of water-free soil.

Determine the hygroscopic moisture of each soil with a special sample at the time of starting the experiment.

This experiment brings out the fact that dry soils absorb only a very small amount of moisture from the air, even when the air is saturated, thus correcting an opinion which is prevalent but erroneous.

Experiment No. 9.

A STUDY OF THE RATE OF RISE OF CAPILLARY WATER IN SOILS.

Use soils Nos. 1, 2, 3, 4, and 5 in this experiment. Place a cheese-cloth disk in the bottom of each tube (fig. 18) to prevent the escape of soil grains. Use the compacting machine to fill the tubes, allowing the weight to drop twice from the 12-inch mark after each measure of soil. Weigh the filled tubes carefully and place them in the frame with the lower ends standing in about 1 inch of distilled water, which should be maintained at constant level. As the water rises by capillarity into the soil the tubes will increase in weight. Weigh the tubes carefully each day for one week, noting the daily increase in each tube and also the total increase for each tube for the period.

Experiment No. 10.

TO TEST THE ADHESIVENESS OF SOILS.

In this experiment soils Nos. 1, 2, 3, and 4 will be used. The adhesiveness will be determined by measuring the force required to overcome the molecular attraction in a column of moist soil 1 square inch in cross section.

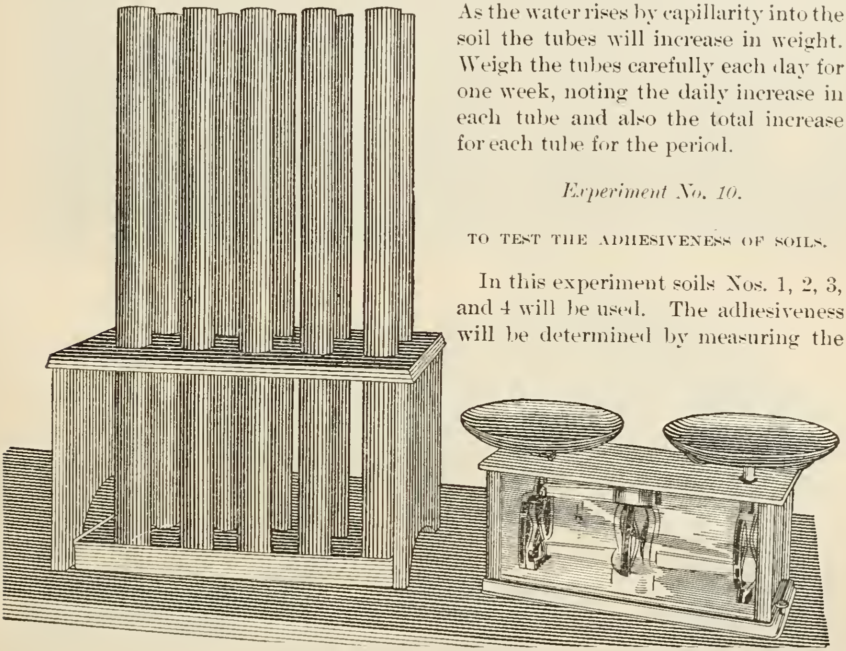


FIG. 18.—Measuring capillarity in soils.

Weigh out roughly 150 grams of soil No. 1 and 180 grams each of Nos. 2, 3, and 4.

Determine the force required to start the empty movable cage (*a*) by running sand from the rubber tube (*b*) into the tin pan (*c*) until the weight is sufficient to cause the cage to move (fig. 19). See to it that the cages are clean and the bearings clean and oiled. The weight of the pan plus the sand it contains represents the force required to overcome the friction of the empty cage, and should be deducted from the total breaking force in each subsequent test of soil.

Empty the weighed sample of soil upon the "mixing board" and add a small quantity of water. Mix soil and water thoroughly by hand working. Enough water should be added to bring the soil to its maximum adhesiveness.

Pack the roll of mud thus formed into the mold, holding the cages together firmly; then with the spatula scrape off the top level with the upper edge of the mold. Attach the pan to the hook at the end of the wire. Pour sand into the pan in a constant stream until the weight is sufficient to separate the cages and break the soil column. Weigh the pan with the sand it contains and deduct therefrom the weight required to overcome the friction of the empty cage. The result represents the adhesive strength of a column of moist soil 1 square inch in cross section.

Care should be exercised to fill the molds as nearly as possible in the same manner in each test.

With this same roll of mud make four tests, using varying amounts of water. The proportion of water may be reduced by adding more dry soil. Test each of the four types of soil in the above manner, using the highest test of each for comparisons of maximum adhesiveness.

Experiments Nos. 11 and 12.

MECHANICAL ANALYSIS OF SOILS.

A modification of the method used in the laboratory of the Bureau of Soils of the United States Department of Agriculture. (Pl. XIV, fig. 1.)

Twenty grams of "fine earth" are weighed out and placed in a porcelain or glass mortar. Enough water is added to give the soil the consistency of paste. The mixture is then rubbed with a rubber-tipped pestle.

In rubbing there should be just enough pressure to detach adhering particles and not enough to break the grains. After five minutes' rubbing more water may be added, and after letting it stand for two or three minutes the turbid liquid is decanted into a beaker, "A." Repeat this pestling and decanting until an examination through the microscope shows the grains to be perfectly clean. When clean the grains show sharp outlines and are transparent, while any adhering finer particles make them round and deeply colored. This pestling may require 15 minutes to an hour or more.

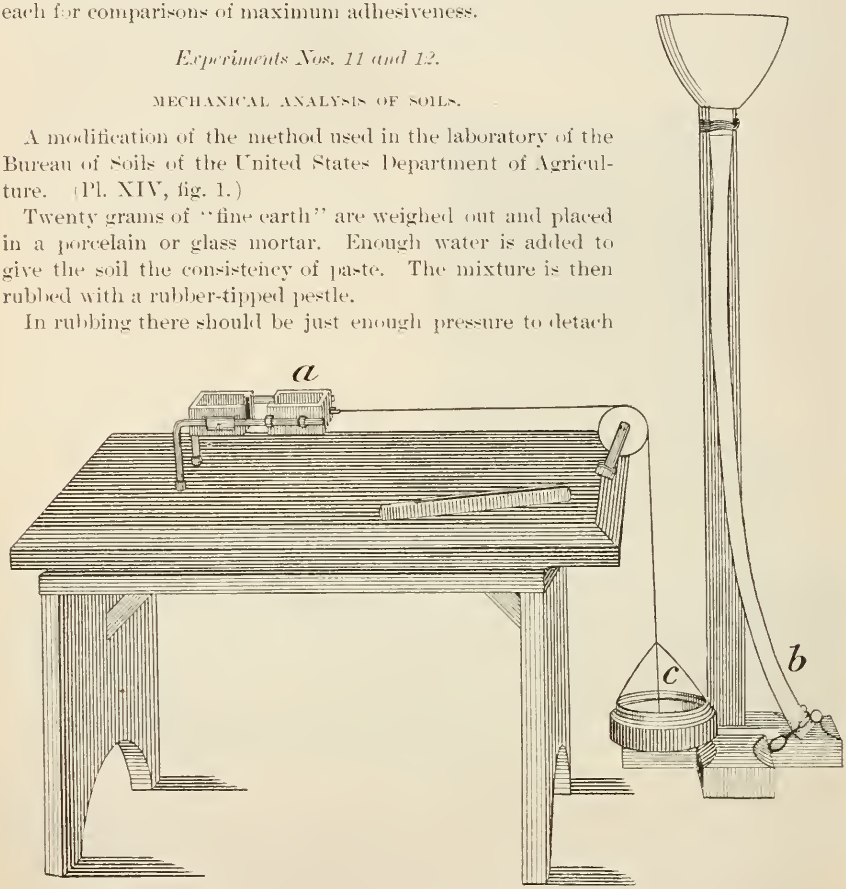


FIG. 19.—Apparatus for testing the adhesiveness of soils.

When the material is thoroughly disintegrated, it is transferred from the mortar to a No. 2 or No. 3 beaker, which is then filled with water, stirred and allowed to stand a few minutes, after which it is carefully decanted, leaving the last 20 or 30 cubic centimeters, the liquor being added to the beaker "A." This is repeated until the sand is free from clay, fine silt, and much of the silt. The sand should be tested with the microscope. All particles smaller than 0.05 millimeter are silt or fine silt

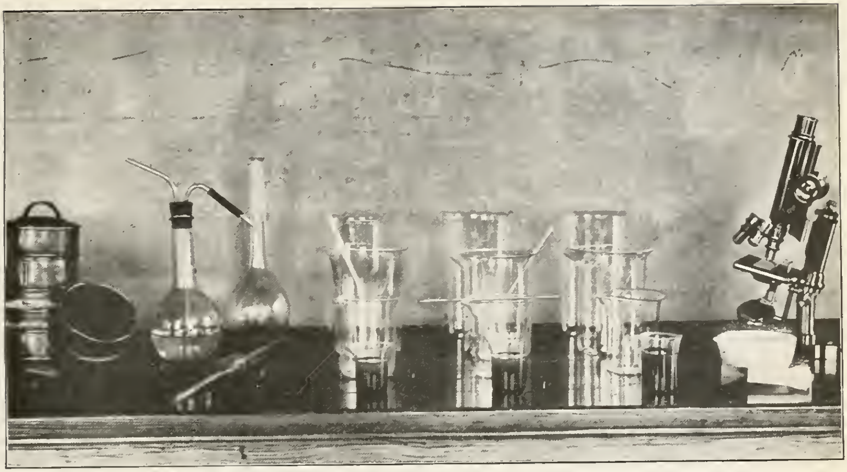


FIG. 1—OHIO STATE UNIVERSITY—MECHANICAL ANALYSIS OF SOIL.

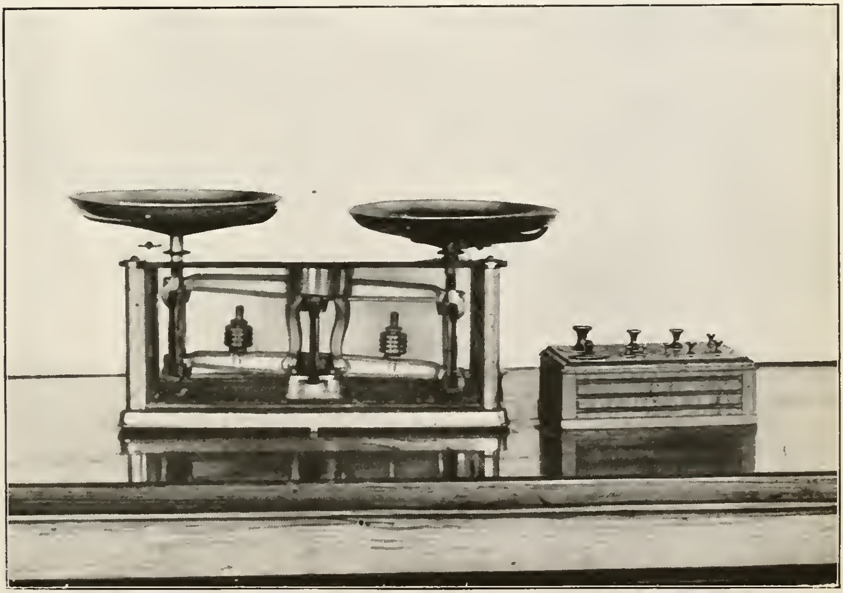


FIG. 2.—OHIO STATE UNIVERSITY—TORSION BALANCE USED IN SOIL PHYSICS LABORATORY.

and should be removed by further decantation. The sediment in the bottom of beaker "A" should also be tested. If it contains particles larger than 0.05 millimeter, the washing or decantation was too rapid. In this case a recovery must be made.

The sand is transferred from the beaker to a porcelain dish and dried. It is then ignited to destroy organic matter, after which it is sifted through a nest of sieves of 1, 0.5, 0.25 and 0.1 millimeter, respectively, that going through the finer sieve being known as very fine sand. These five separations are weighed together before the sifting and separately after sifting.

The amount of silt, fine silt, and clay which was washed away from the sand may be obtained approximately by subtracting the total weight of sand, moisture, and organic matter from the earth taken (20 grams).

Considerable time and skill is required to make the separation of silt, fine silt, and clay. It will not be attempted in this experiment.

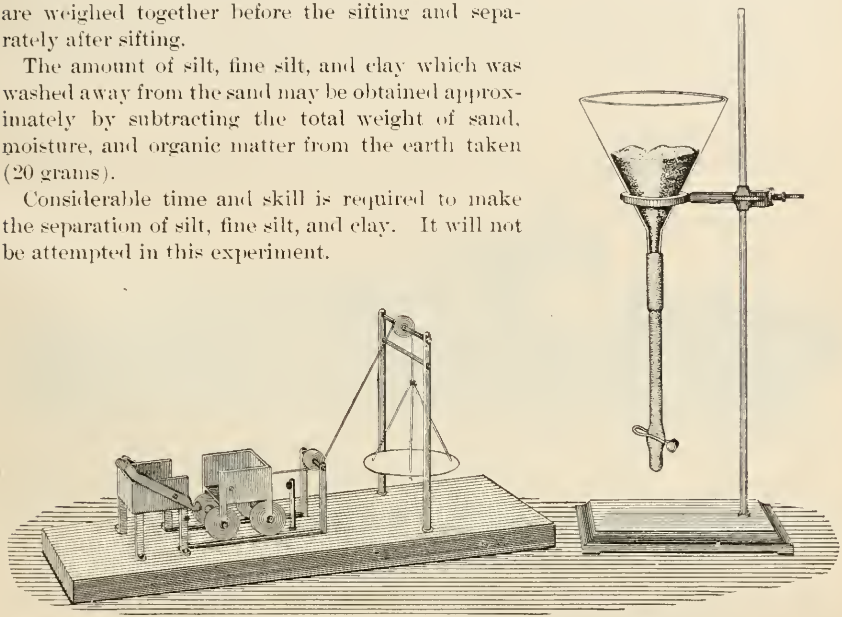


FIG. 20.—Card's apparatus for testing the adhesiveness of soils.

The following are the sizes into which the soil particles are separated:

No. 1. Gravel, 2–1 millimeters.
No. 2. Coarse sand, 1–0.5 millimeter.
No. 3. Medium sand, 0.5–0.25 millimeter.
No. 4. Fine sand, 0.25–0.1 millimeter.
No. 5. Very fine sand, 0.1–0.05 millimeter.
No. 6. Silt, 0.05–0.01 millimeter.
No. 7. Fine silt, 0.01–0.005 millimeter.
No. 8. Clay, 0.005–0.0001 millimeter.

Students are required to keep a careful record of each experiment, and at the end of the term to present plates showing their results, and also illustrations of apparatus used, together with description of the method employed.

EXHIBIT No. 8.

DETAILED SCHEDULE OF LABORATORY WORK.

Advanced course in soils.

September 18 and 19.—Collected samples of soil from fallow, alfalfa, and corn ground to determine moisture content of first and second foot, using sampling tubes and other apparatus, as illustrated in fig. 21.

September 25 and 26.—Collected samples of surface foot of muck, first bottom and second botom soil, for determination of weight per cubic foot of soil under field conditions, using large tube, as illustrated in fig. 21.

October 2 and 3.—Discussion of results as obtained in the above experiments with special reference to the methods of expressing amounts of water in the soil; that is, per cent fresh weight, per cent dry weight, amount of water per cubic foot, and surface inches water.

October 9, 10, 16, 17, 23, 24, 30, and 31.—Mechanical analysis of two samples of soil—a sand and a clay—by the Osborne beaker method, as modified and used by the Bureau of Soils and described in Bulletin No. 4 of the Bureau, pages 8–13.

November 6, 7, 13, and 14.—Separation of "silt," "fine silt," and "clay" by the centrifugal method as used in the Bureau of Soils.

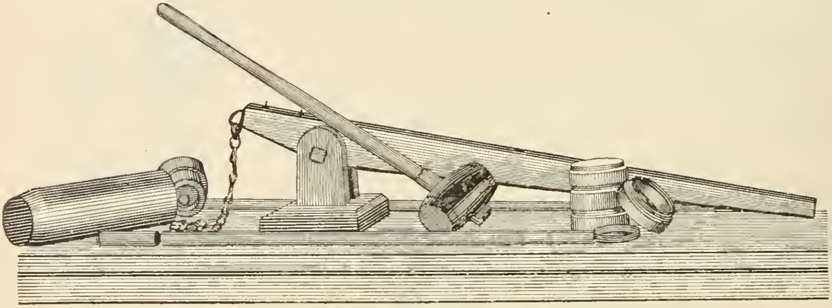


FIG. 21.—Apparatus for taking soil samples.

November 20, 21, 27, 28, and December 4, 5, 11, and 12.—Determination of moisture, soluble salts, and temperature of soils by the electrical method, as described and used by the Bureau of Soils.

EXHIBIT No. 9.

EXAMINATION IN ELEMENTARY COURSE IN FARM CROPS.

The following list of examination questions will serve to indicate the scope of the work covered in the course:

1. Name and explain the reasons for crop rotation.
2. Explain three methods of crop improvement.
3. Give the following statistics on corn and oats for the United States during the last decade: (*a*) Average annual acreage; (*b*) average annual yield; (*c*) average annual yield per acre; (*d*) average value per acre.
4. Name the eight leading States in the production of each of the following crops: Corn, oats, and barley.
5. Describe structure and give chemical composition of a grain of wheat.
6. Name the types of Indian corn and give the distinguishing characteristics of each.
7. Give the chemical composition of corn.
8. Give general directions as to depth of planting, time of planting, and thickness of planting corn.
9. State the reasons for shallow cultivation of corn.
10. Discuss the following: Time of sowing, depth of sowing, and amount of wheat to sow per acre.
11. What points should be considered in distinguishing between varieties of wheat?
12. Discuss briefly the cost and methods of shipping grain from the farms of the Northwest to the Atlantic seaboard.
13. State the conditions of climate, soil, and seed bed best adapted for oats.

14. Discuss depth of sowing, time of sowing, and amount of oats to sow per acre.

15. Name the regions of greatest production of rye and barley in the United States.

16. Give briefly the history of the cultivation of grasses and clovers.

17. Give common and scientific name of six grasses that are grown in Ohio.

18 and 19. Under the following heads discuss common red clover, crimson clover, alsike clover, alfalfa: (*a*) Scientific name; (*b*) value for pasturage and hay; (*c*) climate and soil conditions favorable.

20 and 21. Under the following heads discuss Indian corn as a silage crop: (*a*) Total yield of digestible nutrients as compared with other crops; (*b*) varieties best adapted; (*c*) thickness of planting; (*d*) proper stage of maturity for harvesting.

22. Give directions for growing sugar beets.

Exhibit No. 10.

LIST OF LABORATORY OR FIELD PRACTICUMS IN ELEMENTARY COURSE IN FARM CROPS.

Practicum No. 1.

Eight varieties of corn are grown on the university farm annually for instructional purposes. Students are given this work in the fall term of necessity. Each student is provided with the accompanying score card and asked to judge only the stalks in this exercise.

Practicum No. 2.

The ears, husked from the variety plats, are brought to the laboratory, where a few of the best are selected and the students are asked to score them carefully, according to the card standards as indicated in the following form:

Students' score card.

DENT CORN.

Scale of points.	Standard.	1		2		3		4		5		6		7		8		9		10		11		12	
		Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.
STALK.																									
Height—11 feet for southern, 10 feet for central, and 9 feet for northern Ohio	3																								
Circumference between first and second joints, 3¾–4¼ inches, giving sufficient support to plant without undue coarseness of stalk	3																								
Leaves abundant, indicating growth and adding to the feeding value of the plant	3																								
Husks abundant and moderately adhering for protection of ear against weather and insects	3																								
Barren stalks—should be none	3																								
EARS.																									
Firmness of grains and cob, and of grains on the cob, indicating ripeness and market condition	15																								
Perfection and uniformity of shape of grains making rows regular, and surface of ear smooth and even	6																								
Space between rows should be filled	10																								
Uniformity of color in grains and cobs, indicating trueness to type	10																								
Filling out at ends—ears should be cylindrical and well rounded out at butt and tip	10																								

Students' score card—Continued.

DENT CORN—Continued.

Scale of points.	Standard.	1		2		3		4		5		6		7		8		9		10		11		12	
		Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.	Students.	Corrected.
EARS—continued.																									
Per cent of grain to car, 85 per cent. Estimated, ——, actual, ——	10																								
Length—10 inches in southern and central, and 9 inches in northern Ohio	10																								
Circumference, at two-fifths the length, measuring from base, 7–7½ inches in southern and central, and 6½–7 inches in northern Ohio	8																								
Juncture of cob with stalk, ¾ inch in diameter, giving sufficient support for ear without causing inconvenience in breaking	6																								
Total																									

NAME OF VARIETY.

1. ....
2. ....
3. ....
4. ....
5. ....
6. ....

NAME OF VARIETY—continued.

7. ....
8. ....
9. ....
10. ....
11. ....
12. ....

Student: —— ——.
Date: —— —, ——.

Practicum No. 3.

The selected ears are shelled, weighed, and the figures arranged according to the following outline, which is handed them:

Variety.	Weight ear.	Weight shelled corn.	Per cent shelled corn.	Pounds shelled corn in 1 bushel ears (68 pounds).	Pounds ears in 1 bushel shelled corn.
No. 2					
No. 4					
No. 5					
No. 6					
No. 7					
No. 8					

Remarks: —— ——.

Practicum No. 4.

A STUDY OF THIRTY-NINE VARIETIES OF WINTER WHEAT—CLASSIFICATION.

A. Bearded:
    (*a*) Glumes white.
        (a′) Berry red.
            1. Length of straw less than 3 feet 6 inches.
            2. Length of straw more than 3 feet 6 inches.
        (b′) Berry white.
            3. Length of straw less than 3 feet 6 inches.
            4. Length of straw more than 3 feet 6 inches.

A. Bearded—Continued.
  (*b*) Glumes bronze.
    (a′) Berry red.
      5. Length of straw less than 3 feet 6 inches.
      6. Length of straw more than 3 feet 6 inches.
    (b′) Berry white.
      7. Length of straw less than 3 feet 6 inches.
      8. Length of straw more than 3 feet 6 inches.

B. Beardless:
  (*a*) Glumes white.
    (a′) Berry red.
      9. Length of straw less than 3 feet 6 inches.
      10. Length of straw more than 3 feet 6 inches.
    (b′) Berry white.
      11. Length of straw less than 3 feet 6 inches.
      12. Length of straw more than 3 feet 6 inches.
  (*b*) Glumes bronze.
    (a′) Berry red.
      13. Length of straw less than 3 feet 6 inches.
      14. Length of straw more than 3 feet 6 inches.
    (b′) Berry white.
      15. Length of straw less than 3 feet 6 inches.
      16. Length of straw more than 3 feet 6 inches

Each student is required to hand in a written report of this work.

Practicum No. 5.

About May 1 each year the class spends one period making notes on the condition of 15 to 20 varieties of grasses and clovers in the grass garden for use later in the term when they come to study the varieties more fully.

Practicum No. 6.

The "Howe Grain Tester" is used in testing the purity and weight per bushel of wheat, oats, etc.

Practicums Nos. 7, 8, 9, and 10.

About four periods at the close of the term are given to the study of 15 to 20 varieties of grasses, clovers, and forage plants. Students use the dried specimens in the laboratory as well as the growing plants in the "grass garden." The following outline is given each student, who is required to present an essay on the subject at the end of the term:

DESCRIPTION OF GRASSES AND FORAGE PLANTS.

Describe the following plants from the bundles given and state use, value, and climatic range and adaptation to soil, and give briefly the results obtained with these plants at experiment stations and elsewhere.

The following books may be used for reference, while below will be given references under each variety to results at experiment stations:

Vasey's Agricultural Grasses of the United States; Beal's Grasses of North America; Hackel's True Grasses; Handbook of Experiment Station Work; Grasses of Tennessee, Part II; Grasses and Clovers, Field Roots, Forage and Fodder Plants, by Professor Shaw; Reports of Kansas State Board of Agriculture, 1895 and 1900; Permanent and Temporary Pastures, Sutton; Forage Crops other than Grasses, Shaw; Bulletins of the Division of Agrostology:

1. *Poa pratensis*, L., Kentucky Blue Grass, Bulletins 5 and 15, Illinois Station; Bulletin 20, Mississippi Station.

2. *Agrostis vulgaris*, L., Redtop, Bulletin 15, Illinois Station; Bulletin 20, Mississippi Station.
3. *Phleum pratense.*
4. *Alopecurus pratensis*, L., Meadow Foxtail.
5. *Dactylis glomerata*, L., Orchard Grass, Bulletins 5 and 15, Illinois Station; Bulletin 20, Mississippi Station.
6. *Festuca elatior.*
7. *Festuca pratensis*, Huds., Meadow Fescue, Bulletins 5 and 15, Illinois Station.
8. *Lolium perenne*, L., Perennial Rye Grass, Bulletin 12, Colorado Station; Bulletin 15, Illinois Station; Bulletin 20, Mississippi Station.
9. *Avena elatior*, L., Tall Meadow Oat Grass, Bulletin 15, Illinois Station; Annual Report 1889, Mississippi Station.
10. *Anthoxanthum odoratum.*
11. *Medicago sativa*, L., Alfalfa, Bulletin 2, Colorado Station; Bulletin 15, Illinois Station; Bulletin 20, Mississippi Station; U. S. Department of Agriculture Bulletin 31; Kansas Report, 1895.
12. *Trifolium pratense.*
13. *Trifolium incarnatum*, Crimson or Scarlet Clover, Bulletin 16, Delaware Station; Report 89, Maryland Station; Annual Report 1889, Mississippi Station; Bulletin 44, Virginia Station.
14. *Trifolium hybridum*. Alsike Clover, Report 89, Maryland Station; Annual Report 1889, Mississippi Station; Bulletin 15, Illinois Station.
15. *Trifolium repens.*

THE AGRICULTURAL INSTITUTE OF THE UNIVERSITY OF GÖTTINGEN.

By F. W. Woll,

Assistant Professor of Agricultural Chemistry, University of Wisconsin.

This institution is one of the oldest and foremost of its kind in Germany. It is perhaps better known among American experiment station and college men than any other foreign agricultural institution, on account of the high character of investigational work which has been conducted there during the last half century, and because of the many Americans who have studied in Göttingen during this time.

HISTORY.

Lectures on agriculture have been delivered at Göttingen University since 1770, when J. Beckmann was appointed regular professor of agriculture in the university. He lectured on the subject of agriculture every summer until his death in 1811, and also founded an agricultural-botanical garden to supply instructional material for his lectures, in which all German plants of interest agriculturally were to be grown. It is characteristic that the object of the lectures delivered was not to educate intending farmers, but "to give an insight in farm operations to students who, later on in public service, would be called upon to represent economic interests."

With some interruptions, the lectures were continued until 1852. In that year a special agricultural course of instruction was arranged for at the university, through the efforts of the political economist, Professor Hanssen, of Göttingen University. The course was planned to last four semesters and was placed under the immediate charge of an agricultural faculty composed of four professors, among whom were Wöhler, the famous chemist, and Gripenkerl, who until his death in 1900 filled the chair of agriculture in the university. The plan of study of the new course was comprehensive. Besides the various fundamental natural sciences, it included agricultural chemistry, veterinary science, meteorology, agronomy, farm management, forestry, political science, and rural law. The theoretical studies were to be supplemented by agricultural excursions to estates in the vicinity of Göttingen; special arrangements were made by which the large Government estate, Weende (an old monastery farm, situated about a mile north of Göttingen), could be visited at any time for instructional purposes, and agricultural experiments could also be made on the land belonging to the estate.

The new course started under favorable auspices and received an impetus through the establishment of the Weende Experiment Station in 1857 by the Royal Agricultural Society of Hanover. One object in establishing the experiment station was to supplement the agricultural instruction at the university by demonstrations, "just as if it were an organic part of the same." In 1857 the official name of the course was changed to the Royal Agricultural Academy of Göttingen-Weende, so as to give definite expression to the close connection between the theoretical instruction offered at the university and the practical work at the model Government farm, Weende. The attendance at the academy gradually increased from only four students in 1851 to over forty in the beginning of the sixties. About this time the number of students that came to receive agricultural instruction began to grow smaller, and there was a steady decrease during the following years, until in 1871–72 scarcely more than a dozen attended the academy. The cause of the decreasing attendance during the last years of this period was not difficult to understand in view of the fact that the Agricultural Institute of Halle University, which was established in 1863, showed a steadily increasing attendance during the same time. The Nestor among agricultural university teachers, Julius Kühn, through whose efforts the Halle Agricultural Institute was established, and to whom more than any other man is due the credit for the splendid growth of agricultural university instruction, both in Germany and in other countries, was the first one to call attention to the fact that an agricultural educational institution that is nothing but a professional school does not supply the facilities for instruction which the times demand. Agricultural science is not merely an aggregation of applied sciences, it has its own special sphere, and in order to live and develop it must have opportunities for verification of practical experiences and for investigation of its special problems—similar facilities to those long ago accorded, e. g., to medicine. Teachers who lack this opportunity to verify and enlarge the knowledge of the principles of agriculture can not do the best work for their students or for their profession.

A reorganization of the Göttingen Agricultural Academy took place during 1871–1875, to a large extent in accordance with the ideas which J. Kühn advanced and advocated with signal success. The new agricultural institute of the University of Göttingen (Pl. XV) dates from this period. New buildings were erected, laboratories built, the Weende Experiment Station was removed to the agricultural institute (in 1874), and experimental grounds, with garden and greenhouse, were provided for. Later changes made have been comparatively few, and only one of greater importance, viz. the recent establishment of an agricultural-bacteriological institute, the first one of its kind in the world, so far as is known.

The attendance at the institute during late years, according to the published university catalogue, has been about 30. A number of special students, however, take single lectures or special laboratory work in the institute without being registered as agricultural students, so that the actual number of students attending lectures of professors or working in the laboratories of the institute is somewhat greater than the figure given, but is at any rate small compared with the attendance in agricultural educational institutions of similar standing in this country.

PRESENT ORGANIZATION.

The Göttingen Agricultural Institute, as organized at present, is composed of six different departments, viz:

(1) General agriculture and animal husbandry, in charge of the director of the institute, Prof. W. Fleischmann.

(2) Agricultural chemical laboratory of the university, Prof. B. Tollens.

(3) Agricultural experimental grounds, Prof. C. von Seelhorst.

(4) Animal physiological experiment station, Prof. Franz Lehmann.

(5) The veterinary institute of the university, Prof. H. J. Esser.

(6) The agricultural bacteriological institute of the university, Prof. Alfred Koch.

Assistants in the agricultural institute.—In one respect there is a marked difference between the Göttingen Agricultural Institute and Station and our American colleges and stations, viz, the abundant help, skilled or otherwise, available for the routine work to be done. The janitors of the European stations do a large amount of semichemical work and render valuable service in many ways that those in America are never called upon to do; the assistants or division heads have in

GÖTTINGEN AGRICULTURAL INSTITUTE—MAIN BUILDING.

general complete charge of all routine work in their respective departments, such as laboratory instruction and the preparation of demonstration material for lectures, thus enabling the director or professor to devote nearly his undivided time and energies to work of a higher grade and to his own studies. The following statement gives the number of assistants and janitors or unskilled laborers, in the Göttingen Agricultural Institute during the season of 1901:

Departments.	Assistants.	Janitors or laborers.
Dairy laboratory	1	1
Agricultural chemical laboratory	1	1
Plant culture station	3	[a] 9
Animal physiological station	3	2
Veterinary department	1	1
Agricultural bacteriological institute	1	1
Total	10	[b] 15

[a] Three in winter.

[b] Nine in winter.

REQUIREMENTS FOR ADMISSION.

To be admitted as a student in the agricultural institute, as in all other departments of the university, one must go through the formality of matriculation. Germans are matriculated when they are graduates of a gymnasium (high school) or have a similar preliminary education, while for foreigners a diploma from a recognized college or university is required. Some latitude as to preliminary education required is allowed in admitting agricultural students, and older farmers, as well as others who wish to attend lectures, may be admitted as Hospitanten or Hörer (special students) almost without regard to previous training. Several years of practical farm work are considered highly desirable, and students are urged to come to the university so equipped, but previous training in this line is not required. A very large proportion of the agricultural students are the sons of more or less well-to-do farmers, who have taken part in the farm work when their school studies allowed it, and who expect to return to the home farm on the successful completion of their university work; others expect to seek positions as foremen on large estates, or as teachers in the lower agricultural schools.

COURSE OF STUDY.

There is no rigid course of study offered in the agricultural institute, nor is the duration of the course at all fixed; it is expected that the required studies can be finished in five or six semesters, but it depends on the student himself whether or not he will present himself for examinations after this time. The following studies are required in the agricultural course as arranged at the present: History of agriculture; plant production, horticulture, plant diseases; animal husbandry—breeding, rearing, and feeding of horses, cattle, sheep, swine, and poultry; veterinary science: agricultural physics—drainage, irrigation, surveying, agricultural machinery and apparatus, farm buildings; farm management and farm bookkeeping. In addition to these professional studies the following fundamental sciences are required: Chemistry (general, industrial, agricultural), physics, botany (general, systematic, physiological), bacteria and yeasts, zoology, geology and mineralogy, meteorology, political economy, and rural law. The instruction is imparted by means of lectures, laboratory work, demonstrations, excursions, and seminars.

Owing to the fact that many of the agricultural students have a limited previous training, the lectures offered in the agricultural institute at Göttingen, as in other German institutions of this class, are, as a general rule, quite elementary. It is well for American students intending to study in Europe to bear this in mind, as it will save them from disappointment later on. The information conveyed in a course of lectures which may not cover more than two or three hours a week for a brief German university semester—sixteen to seventeen weeks in winter and twelve to thirteen weeks in summer—must necessarily be general and can present only the main facts of the subject treated. And after all, the knowledge thus conveyed is but a small part of the benefit derived from attending such a course of lectures; of far higher value to the young student must be counted the opportunity of becoming acquainted with a thinker, to note his methods of treatment and presentation, and to catch something of the enthusiasm of a scholar.

METHODS OF INSTRUCTION.

The lectures delivered are, whenever possible, illustrated by charts, maps, museum specimens, or simple experiments. In the lectures on plant nutrition, for example, the whole lecture table is generally covered with specimens of minerals, soils, soil constituents, or fertilizers, according to the subject to be treated in the lecture. A synopsis of each lecture, or manifold copies of tables of figures and the like, to which reference will be made in the lecture, are also furnished by some professors. The literature on the subject treated is also generally shown, either at the beginning of the course or as a special topic is reached, and usually sent around the class for inspection, in the same way as the specimens referred to in the lectures. Electric or other kinds of stereopticons are used at times for exhibiting pictures, charts, etc., on a screen, but not to such an extent as in our better-equipped institutions, nor as successfully, so far as my experience goes.

INSTRUCTION IN AGRONOMY.

The method of instruction in agronomy adopted at the Göttingen Agricultural Institute is of interest to the student of agriculture because of the rich material for illustration and demonstration at hand and the excellent opportunity which the excursions made to the many large estates in the surrounding country offer for studying different systems of farming under German conditions. The American student will find the work done in this line full of suggestions and directly applicable at least to Eastern conditions. The instruction is carried on by means of lectures, laboratory work, demonstration on the experimental grounds and in the garden, agricultural excursions, and the agricultural seminar. This work is in charge of the director of the agricultural experimental grounds, Prof. C. von Seelhorst, who is also professor of agronomy in the university.

Lectures and laboratory work.—The courses of lectures offered in agronomy are, in the winter semester, general plant production (plant life) and breeding of agricultural crops; in the summer semester, culture of special crops, and weeds and plant diseases. The characteristics of the various kinds of grains, roots, tubers, and other agricultural crops are discussed in the special course, specimens of grain in the sheaf, potatoes, seeds, etc., being supplied in each case, and botanical charts and other illustrative material shown. The laboratory instruction is given throughout the year one afternoon in the week. It consists of microscopical and agricultural examinations of concentrated feeding stuffs as to more important adulterations, quality, etc.; further seed tests, and, in the winter semester, studies of plant diseases. Chemical analyses of crops, soils, fertilizers, etc., are made only as required in special investigations, the general methods adopted in the laboratory work being such as the students will be likely to use and can use later on in their work on the farm.

Demonstrations.—The demonstrations on the experimental grounds, in the garden and the greenhouse are of special interest and value to the students. They are given once a week (Monday morning from 7 to 8) during the whole year so long as there is anything of interest agriculturally to be seen outside. The writer attended all demonstrations given during the summer semester of 1901, and was pleased to observe the interest which the students evidently took in the demonstrations, as well as agreeably surprised to note the regularity with which the students met at this rather unusual hour, a regularity which was the more surprising as the attendance at lectures, in the summer semester at least, at most German universities is far from regular. The popularity of the professor in charge doubtless contributed to bring about this result, but not more than did the practical nature of the subject and the abundant material for demonstration at hand. In these demonstrations the professor would conduct the class to the particular part of the grounds which he wished to speak about, and would then explain the experiments in progress and call attention to special points of importance. The next and following weeks a stop would be made at the same plats to note the development of the crop under the different conditions, differentiation of varieties or of crops under different systems of fertilization, etc. The continuity of the demonstrations gave these talks increased value, the eyes of the students became trained to detect minute differences in the color or luxuriance of plants, and they could follow the gradual differentiations in plants from week to week due to different conditions of fertilization or other influences. The effects of a scarcity or an excess of moisture; effects of hail on different crops, and how they gradually recover, or fail to recover, from these effects; estimation of the damage done by hail, weeds, attacks of insect, or fungus diseases; identification of these, their methods of attack and distribution, and how to combat them; estimations of yields of different crops, etc., are some of the almost innumerable subjects which furnish a well-informed teacher material for lectures in the field. The lectures were informal talks, often interrupted by questioning of the students as to their opinions of matters observed or to be observed. The students would jot down in their note books, although not as frequently as desirable, facts or suggestions brought out. Aside from the fact that the demonstrations served as a convenient method of gathering a large amount of direct practical information on farm topics, they were of great value to the students in teaching them to use their eyes and to apply knowledge obtained in other disciplines, and last, but not least, served to create or maintain an interest and enthusiasm for farm matters which perhaps no other method of instruction would be likely to equal.

It might be thought that there could hardly be anything new or interesting to note on grounds but little over 15 acres in area when the demonstrations came as often as once every week, but with the rich material available, which included dozens of different plat experiments with all kinds of farm crops, rotation experiments, fertilizer tests, pot experiments, etc., this was not the case; on the contrary, the hour proved invariably too short to go over only the portion of the grounds planned each time. The arrangement of the German university year is most favorable for observing the larger share of the round of farm operations. The summer semester covers the time from the end of April to the beginning of August, and the winter semester the time from the end of October to the beginning of March. In these two periods nearly the whole growing periods of most farm crops fall, and most of the important farm work, like preparation of the land in the spring; seeding of spring grains; planting of peas, beans, root crops, and potatoes, and cultivation of the same; cutting and curing of hay; cutting, stacking, and harvesting of small grains, peas, and other crops; securing the second crop of hay; harvesting and storing of root crops and potatoes; preparing and seeding land to winter grains, etc. Thus a full year's attendance at the demonstrations will bring all the main farm operations up for discussion; it will acquaint the students with the best practices in all cases, and will give them a fund of combined practical and theoretical knowledge which can be drawn upon for assistance throughout their lifetime.

Excursions.—A fourth method of instruction in agronomy at Göttingen Agricultural Institute is supplied by the agricultural excursions which are made to estates in the vicinity of Göttingen once every week, generally Saturday afternoons, but at times covering one or more days. The professor and students are shown around the premises by the owner, or in his absence, by his foreman, who explains the system of farming followed, the character of soil and manuring in the different fields, and the history of these for a couple of years back as to crops grown and systems of fertilization. Stables, barns, tool sheds, and other farm buildings are also visited, and the owner's experience is ascertained in each case, questions put by the professor or any in the party being as a rule answered in an open, businesslike way. The excursion generally ends with a short social time, when light refreshments are often served, and points not previously touched upon, or more general topics connected with the farm management, are brought up and discussed. The party is apparently heartily welcome at all the places visited, the farmers seeming to consider it an honor to receive their visitors, in spite of the fact that the visit in some cases is a yearly or even a half-yearly affair. The hospitable spirit shown toward the professor and the young men who are about to enter into practical farm work themselves, is strong evidence of the high esteem in which German farmers hold their higher agricultural educational institutions and the men who are intrusted with the instruction of their sons or neighbors' sons in their future profession.

As the excursions are under the charge of the professor of agronomy they are necessarily of greater benefit to students in furnishing information in this line than along the line of animal husbandry, or special dairy husbandry. In the latter subjects there is, in general, less to be learned in a German university, or in Germany on the whole, by an American student, than in almost any other branch of study, so far as the writer's experience goes.

The relations of the Government estate, Weende, to the agricultural institute are somewhat different from those of the other estates visited, in so far as the renter is under contract to give agricultural students occasional talks on the work in progress on the estate, and to allow inspection of the estate by the students at any time. The fact that the present renter of the estate, Oekonomierat Beseler, is one of the prominent grain growers of Germany, who, besides being the originator of a number of improved strains of small grains, especially wheat and oats, is a progressive farmer and an excellent instructor, makes the excursions to Weende of the highest value to the agricultural students. The Weende estate has a total area of 672 acres, of which about 480 acres of fields and meadows lie in the alluvial or diluvial soil of the Leine Valley, and the rest is keuper (pœcilitic) soil. To the Weende estate belongs also the Deppoldshausen branch farm, situated on the Göttingen forest plateau, about 1,000 feet high, and 3 miles distant from Weende. This farm lies in the shell-lime formation, and has a thin clay soil calling for methods of farming entirely different from those of the valley farms; it includes an area of 360 acres of cultivated land and 77 acres of pastures. The system of farming followed on estates in the vicinity of Göttingen is mostly grain raising and sugar-beet culture, but there are also a number of large dairy farms that are visited at intervals.

Seminar.—The fifth branch of the instruction in plant production in Göttingen is the agricultural seminar. This is held in conjunction with the agricultural excursions, and meets once a week from 8 to 9.30 in the evening (6 to 7.30 in the winter), the professor of agronomy conducting the seminar. One of the students, acting as reporter on the agricultural excursion, prepares a paper on the estate visited, which is read at the seminar. In this a full account is given of what has been seen or learned about the place visited, and criticisms are offered as to farming methods, etc. The discussion following the paper brings out important points that were not considered in the paper, and enlarges upon such not sufficiently elucidated. The business side of the farm operations, the economy of systems of fertilization, the statics of fertilizing ingredients in the soil, system of crop rotation adopted, and special conditions of soil or markets under which the farmer works are among the subjects likely to come up for discussion each time. The regular attendance of the students at the seminar, and the lively discussions which generally arise as to methods of farm practice or principles underlying these, testify to the interest which the students take in this work and the benefit which they derive from taking part in the seminar.

FACILITIES FOR INSTRUCTION.

The facilities for work in the various departments are in general up to the requirements of modern educational institutions, even according to the standards common in this country, where, as a rule, buildings and equipment have been provided for the special purpose in view, and are not, as is often the case abroad, the adapted inheritance of earlier times. An American student will most likely be surprised, however, to note the small scale on which the equipment is arranged at Göttingen, as at nearly all other German agricultural colleges.

The dairy and bacteriological laboratory of Professor Fleischmann, whose name is identified with the development of dairy science in all its phases from its beginning until the present time, consists of two rooms, one about 24 by 40 feet and the other 24 by 14 feet, with accommodations for less than half a dozen students. The agricultural chemical laboratory (Professor Tollens) consists of two rooms, one for qualitative and quantitative analysis, with accommodations for 36 students, and one for advanced or thesis work, for 10 students. The general auditorium or lecture room of the agricultural institute has a seating capacity of about 36, and is never crowded—less than ever later in the semester, owing to the German system of noncompulsory attendance.

For purposes of instruction and demonstration in agronomy use is made of the experimental grounds, greenhouse, and other equipment of the plant-culture experiment station. The experimental grounds have a total area of about 15 acres, and adjoin the agricultural institute on the north (Pl. XVI, figs. 1 and 2). Experimental work on this land was begun by Professor Drechsler in the beginning of the seventies, and has included trials of systems of rotations, variety tests of farm crops, fertilizer experiments, and improvement of cereals and other crops through continued selection. The diagram herewith given shows the divisions of the experimental grounds (fig. 22). The crops grown on these in 1901 were as follows:

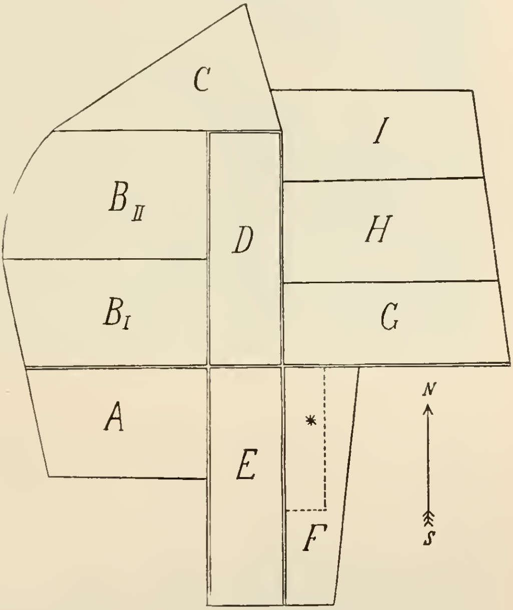


Fig. 22.—Plan of experimental grounds at Göttingen Agricultural Institute.

Field A.—Göttinger rye.

Field B I.—Square-head wheat.

Field B II.—Potatoes, 22 varieties. Potash fertilizer experiments.

Field C.—Red clover.

Field D.—Peas, 2 varieties, and beans. Potash fertilizer experiments.

Field E.—Rye, flax, winter wheat, mangel-wurzels, barley, beans, potatoes, spring wheat, oats, sugar beets, and potatoes. Fertilizer experiments.

Field F.—Plant breeding experiments with rye, winter wheat, spring wheat, oats, sugar beets, and potatoes. Fertilizer experiments with oats and sugar beets.

Field F (south of plant-breeding plats).—Clover, tests of 30 varieties of different origin; spring wheat, 8 varieties; potatoes, breeding experiments with 4 varieties.

Field F (east of plant-breeding plats).—Sugar and fodder beets (experiments with different distances of planting); potatoes, 5 varieties; peas, 2 varieties.

Field G.—Oats, Göttinger and Beseler's improved, with clover.

Field H.—Root crops: Sugar beets, mangel-wurzels. Potash fertilizer experiments.

Field I.—Square-head wheat.

In the trial garden small plats are grown of all plants of agricultural importance to northern Germany, the different kinds of grasses and fodder plants, cereals, root crops, small fruits, weeds, etc. Mixtures of grasses and leguminous plants are also grown under different systems of fertilization, to study the effect or to obtain demonstration material for showing the effect of certain fertilizers in favoring the growth of some plants and checking that of others. Similar experiments were also conducted during the season of 1901 in pots in the greenhouse, under liberal or scant supplies of water, in the study of the effect of water supply on the action of different fertilizers or combinations of such.

Pot experiments are conducted in the greenhouse shown in Pl. XVII. The dimensions of the greenhouse are 23 by 49 feet, with a workroom added, 13 by 36 feet. It has accommodations for about 600 pots, which are placed on trucks and in good weather always kept outside. The experiments are conducted according to the plan worked out at the Darmstadt station. The general problem studied during late years is the influence of the water supply on the utilization of different kinds of fertilizers by cereals, grasses, and other farm crops. The laboratory investigations are chiefly supplementary to experiments conducted in the field, garden, or greenhouse, the main work of the assistants being the chemical analysis of materials harvested, soils, fertilizers, etc. A great deal of independent research work has, however, also been conducted in the laboratory, and has from time to time been published in the periodical literature, especially in the Journal für Landwirtschaft.

Library and museum.—A description of a German agricultural institute would be incomplete without a mention of its library and museum, both of which form all-important parts of the facilities for instruction and research. The library of the Göttingen Agricultural Institute is small, less than 3,000 volumes, but is very complete in German works on agriculture and allied subjects. To an American

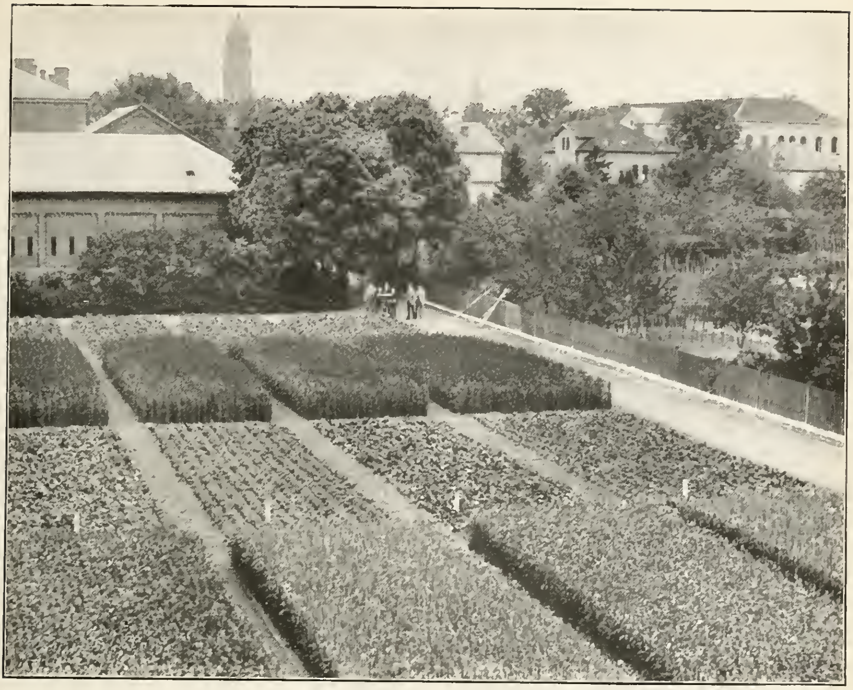


FIG. 1.—GÖTTINGEN AGRICULTURAL INSTITUTE—LOOKING SOUTHEAST.

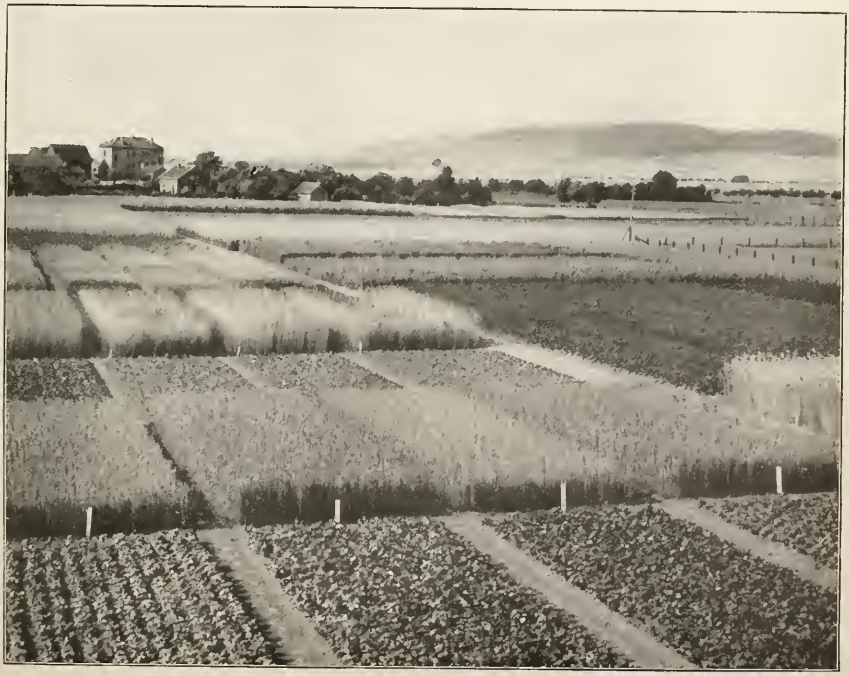
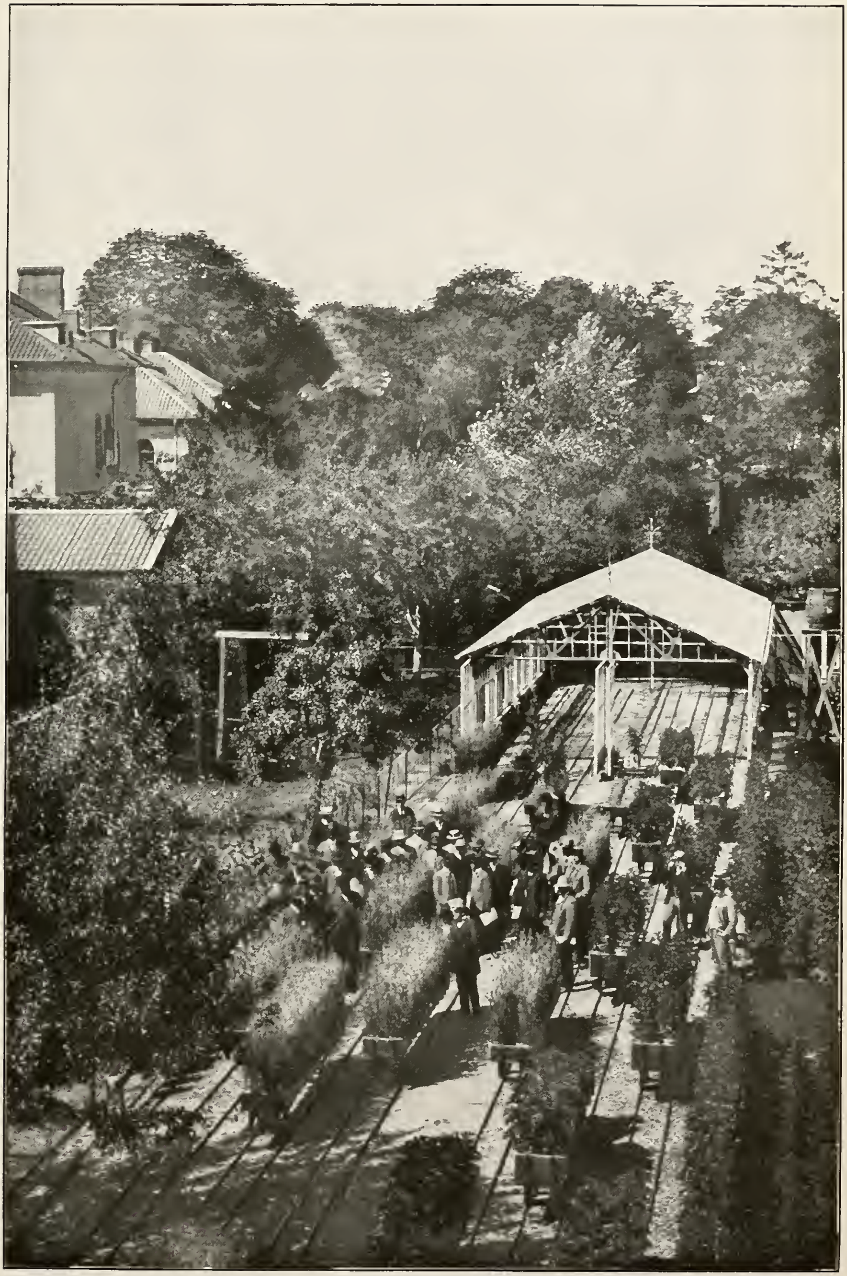


FIG. 2.—GÖTTINGEN AGRICULTURAL INSTITUTE—LOOKING NORTHEAST FROM INSTITUTE BUILDINGS ACROSS THE EXPERIMENT PLATS.



GÖTTINGEN AGRICULTURAL INSTITUTE—GREENHOUSE.

student the absence of the best foreign (English or American) agricultural literature, in this library as in all other German libraries with which the writer is acquainted, will seem strange. In the laboratories of the institute are found special small, but good, reference libraries, which are accessible at all times and are of great service to students. There is also a reading room, where current numbers of the leading German (and other continental-European) agricultural papers and scientific magazines are kept.

The museum of the Göttingen Agricultural Institute was founded in 1851 by Professor Gripenkerl, and therefore represents half a century's growth. The agricultural faculty have here from year to year deposited collections in their respective lines of instruction and investigation, with the view of making it valuable for instructional purposes rather than of establishing an agricultural museum. The collection of feeding stuffs contains samples of feeds used by Henneberg in his fundamental studies on the nutrition of farm animals, and numerous other specimens in the museum bear testimony of investigations conducted at Göttingen during the latter half of the nineteenth century. The rich collections thus accumulated form invaluable material for demonstration and are constantly utilized by the professors in their lectures.

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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 128.

A. C. TRUE, Director.

STATISTICS
OF THE
Land-Grant Colleges and Agricultural Experiment Stations
IN THE
UNITED STATES
FOR
THE YEAR ENDED JUNE 30, 1902.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

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OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., March 5, 1903.

Sir: I have the honor to submit herewith some statistics of the land-grant colleges and agricultural experiment stations for the year 1902, compiled under my direction by Miss Marie T. Spethmann, of this Office, and to recommend their publication as Bulletin No. 128.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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KEY TO ABBREVIATIONS.

Agr., Agriculture, Agricultural.
Archi., Architecture.
Biol., Biology, Biological.
Bot., Botany, Botanical.
Chem., Chemistry, Chemical.
Clas., Classical.
Elect., Electrical, Electricity.
Engin., Engineer, Engineering.
Engl., English.
Ent., Entomology.
For., Forestry.
Geol., Geology, Geological.
Hist., History.
Hort., Horticulture.
Husb., Husbandry.
Indus., Industrial, Industries, Industry.
Irrig., Irrigation.
Lang., Language, Languages.
Lat., Latin.
Libr., Library, Librarian.
Lit., Literature.
Math., Mathematics, Mathematical.
Mech., Mechanics, Mechanical.
Med., Medical, Medicine.
Metal., Metallurgy.
Pedag., Pedagogics, Pedagogy.
Phar., Pharmacy, Pharmaceutical.
Philos., Philosophy.
Phys., Physics, Physical.
Prep., Preparatory.
Sci., Science, Sciences, Scientific.
Sten., Stenography.
Tech., Technical.
Veg., Vegetable.
Vet., Veterinary, Veterinarian.
Zool., Zoology, Zoologist.

STATISTICS OF LAND-GRANT COLLEGES AND AGRICULTURAL EXPERIMENT STATIONS, 1902.

The following statistical statements relate to the institutions established under the acts of Congress of July 2, 1862, and August 30, 1890, most of which maintain courses of instruction in agriculture, and to the agricultural experiment stations, which, with a few exceptions, are organized under the act of Congress of March 2, 1887, and are conducted as departments of the institutions receiving the benefits of the land-grant act of July 2, 1862. These statistics have been compiled in part from replies to a circular of inquiry sent out from the Office of Experiment Stations and in part from the annual reports of the presidents of these institutions made on the schedules prescribed by the Commissioner of Education. Tables showing the annual disbursements on account of the acts of Congress of March 2, 1887, and August 30, 1890, prepared in the departments of the Treasury and the Interior, are also included. Owing to the complex organization of many of the institutions, it is impracticable to give exactly comparable statistics in all cases, and in some instances the data furnished are incomplete.

SUMMARY OF STATISTICS OF LAND-GRANT COLLEGES.

Educational institutions receiving the benefits of the acts of Congress of July 2, 1862, and August 30, 1890, are now in operation in all the States and Territories except Alaska. The total number of these institutions is 66, of which 63 maintain courses of instruction in agriculture. The aggregate value of the permanent funds and equipment of the land-grant colleges and universities in 1902 is estimated to be as follows: Land-grant fund of 1862, $11,369,031.50; other land-grant funds, $1,079,148.99; other permanent funds, $16,354,870.55; land grant of 1862 still unsold, $4,315,546.06; farm and grounds owned by the institutions, $5,198,577.86; buildings, $20,082,610.60; apparatus, $1,670,306.12; machinery, $1,545,508.28; libraries, $1,979,343.69; miscellaneous equipment, $3,949,944.60; total, $67,544,888.25. The income of these institutions in 1902, exclusive of the funds received from the United States for agricultural experiment stations ($719,469.72), was as follows: Interest on land grant of 1862, $682,960.65; interest on other land grants, $72,098.63; United States appropriation under act of 1890, $1,200,000; interest on endowment or regular appropriation, $552,363.08; State appropriation for current expenses, $1,694,949.51; State appropriation for buildings or other special purposes, $2,066,341.70; endowment, other than Federal or State grants, $582,163.08; tuition fees, $664,154.97; incidental fees, $500,064.90; miscellaneous, $1,151,176.30; total, $9,166,272.82. The value of the additions to the permanent endowment and equipment of these institutions in 1902 is estimated as follows: Permanent endowment, $1,115,905.46; buildings, $1,785,125.39; library, $134,102.70; apparatus, $103,433.83; machinery, $150,925.54; miscellaneous, $123,710.04; total, $3,413,202.96. The number of persons in the faculties of the colleges of agriculture and mechanic arts was as follows: For preparatory classes, 346; for collegiate and special classes, 1,797; total, 2,229. In the other departments the faculties aggregated 1,050, making a grand total of 3,279 persons in the faculties of the land-grant institutions. The students in 1902 were as follows: (1) By classes—preparatory, 8,272; collegiate classes, 17,212; short course or special, 5,114; post graduate, 483; other departments, 16,334; total, 46,699. (2) By courses—agriculture, 6,299; mechanical engineering, 4,702; civil engineering, 2,146; electrical engineering, 1,814; mining engineering, 935; chemical engineering, 499; architecture, 336; household economy, 2,706; veterinary science, 977; dairying, 1,372; military tactics, 12,996. The graduates in 1902 were 4,443, and since the organization of these institutions, 50,026. The average age of graduates in 1902 was 21 years and 11 months. The total number of volumes in the libraries was 1,795,607. The total number of acres of land granted to the States under the act of 1862 was 10,110,852, of which 1,010,845 are still unsold.

SUMMARY OF STATISTICS OF THE STATIONS.

Agricultural experiment stations are now in operation under the act of Congress of March 2, 1887, in all the States and Territories and in Alaska, Hawaii, and Porto Rico. In Connecticut, New Jersey, New York, Hawaii, Missouri, Alabama, and Louisiana separate stations are maintained wholly or in part by State funds. A number of substations are also maintained in different States. Excluding the substations, the total number of stations in the United States is 60. Of these, 55 receive appropriations provided for by act of Congress.

The total income of the stations during 1902 was $1,328,847.37, of which $720,000 was received from the National Government, the remainder, $608,847.37, coming from the following sources: State governments, $369,771.12; individuals and communities, $2,301.38;

fees for analyses of fertilizers, $80,942.36; sales of farm products, $105,644.60; miscellaneous, $50,187.91. In addition to this, the Office of Experiment Stations had an appropriation of $139,000 for the past fiscal year, including $12,000 for the Alaska experiment stations, $12,000 for the Hawaiian investigations, $12,000 for the Porto Rican investigations, $20,000 for nutrition investigations, and $50,000 for irrigation investigations. The value of additions to the equipment of the stations in 1902 is estimated as follows: Buildings, $176,113.78; libraries, $11,941.98; apparatus, $19,727.94; farm implements, $14,982.56; live stock, $20,554.27; miscellaneous, $19,509.09; total, $262,829.62.

The stations employ 710 persons in the work of administration and inquiry. The number of officers engaged in the different lines of work is as follows: Directors, 53; assistant and vice-directors, 18; special agents in charge, 3; chemists, 151; agriculturists, 54; agronomists, 7; animal husbandmen, 25; horticulturists, 73; farm foremen, 25; dairymen, 34; botanists, 50; entomologists, 50; zoologists, 6; veterinarians, 27; meteorologists, 12; biologists, 8; physicists, 5; geologists, 4; mycologists and bacteriologists, 20; irrigation engineers, 9; in charge of substations, 14; secretaries and treasurers, 25; librarians, 10; and clerks and stenographers, 41. There are also 103 persons classified under the head of "miscellaneous," including superintendents of gardens, grounds, and buildings; apiarists, vegetable, plant, and animal pathologists; herdsmen, poultrymen, etc.

Three hundred and sixty-four station officers do more or less teaching in the college with which the stations are connected.

The activity and success of the stations in bringing the results of their work before the public continue unabated. During the year they published 373 annual reports and bulletins, which are many more than are required by the Hatch Act. These were supplied to over half a million addresses on the regular mailing lists. A larger number of stations than formerly supplemented their regular publications with more or less frequent issues of press bulletins, and most of the stations report a large and constantly increasing correspondence with farmers on a wide variety of topics.

STATISTICS OF THE LAND-GRANT COLLEGES AND UNIVERSITIES.[a]

Unless otherwise specified, the statistics reported in the tables are for the institutions as designated in the list given below:

TABLE 1.—*Institutions established under the land-grant act of July 2, 1862, and their courses of study.*

[All of the institutions in this list, except those marked with an asterisk (*), maintain courses of instruction in agriculture.]

State or Territory.	Name of institution.	Location.	President.	Collegiate courses of study (undergraduate).	
				Four-year courses and degrees.	Short courses.
Alabama	Alabama Polytechnic Institute.	Auburn	C. C. Thach, M. A.	Chem. and agr., civil engin., elect. and mech. engin., phar., general chem. and metal. (B. S.).	Agr., mech. arts, phar. (2 yrs.).
	Agricultural and Mechanical College for Negroes.	Normal	W. H. Councill, Ph. D	Sci. (B. S.), agr. (B. A. S.), mech. (B. M. S.).	Indus. and lit. studies (1 to 3 yrs.).
Arizona	University of Arizona	Tucson	F. Y. Adams, M. A.	Lit., sci., engin., chem., mining, agr. (B. S.)	Mining, assaying (2 yrs.).
Arkansas	Arkansas Industrial University.	Fayetteville	H. S. Hartzog, LL. D.	Agr., full course (B. S.); agr., special course (B. A. S.); mech. engin. (B. M. E.), elect. engin. (B. E. E.); civil engin. (B. C. E.), sci. (B. S.), liberal arts (B. A.).	Mech. engin., elect. engin., normal (2 yrs.).
	*Branch Normal College	Pine Bluff	Isaac Fisher	Collegiate (B. A.)	Normal, domestic econ., typewriting.
California	University of California	Berkeley	B. I. Wheeler, Ph. D., LL. D.	Letters (B. A.), social sci. (B. L.), natural sci., commerce, agr., mech. mining, civil engin., chem. (B. S.).	Prep. med. (3 yrs.).
Colorado	The State Agricultural College of Colorado.	Fort Collins	B. O. Aylesworth, M. A., LL. D.	Agr., mech. engin., civil and irrig. engin., ladies', archi., vet. sci. (B. S.).	Commercial (2 yrs.).
Connecticut	Connecticut Agricultural College.	Storrs	R. W. Stimson, M. A., B. D.	(B. S.)	Dairy, creamery, for., pomol. (12 weeks), poultry (6 weeks), 20 miscellaneous 10-day courses.
Delaware	Delaware College	Newark	G. A. Harter, M. A., Ph. D.	Clas., Lat. sci. (B. A.), agr., general sci. (B. S.), civil engin. (B. C. E.), mech. engin. (B. M. E.), elect. engin. (B. E. E.).	Agr. (2 yrs.), agr. (winter, 3 months).
	State College for Colored Students.	Dover	W. C. Jason, M. A., B. D.	Clas. (B. A.), sci. (B. S.), agr. (B. Agr.), engin. (B. E.),	Normal (3 yrs.).
Florida	Florida Agricultural College	Lake City	T. H. Taliaferro, C. E., Ph. D.	Agr., mech. engin., chem., Lat., sci., civil engin. (B. S.), general sci., clas. (B. A.).	Mech. arts (2 yrs.), business, stenography, and typewriting (1 yr.).
	Florida State Normal and Industrial College.	Tallahassee	N. B. Young, M. A		Normal, academic, and industrial.

Georgia	Georgia State College of Agriculture and Mechanic Arts.	Athens	H. C. White, Ph. D	General sci., agr., civil engin., elect. engin. (B. S.).	Agr. (winter, 3 months).
	Georgia State Industrial College.	College	R. R. Wright	Collegiate (B. A.)	Normal (3 yrs.).
Idaho	University of Idaho	Moscow	J. A. McLean, Ph. D	Clas. (B. A.), agr., sci., civil engin. (B. S.). mining engin. (B. M. E.), music (B. M.).	Agr. (3 yrs.), farmers' 6 weeks.
Illinois	University of Illinois	Urbana	A. S. Draper, LL. D	Lit. and arts (B. A.), engin., sci., agr. (B. S.), music (B. M.), libr. sci. (B. L. S.), phar. (Ph. G.), phar. chem. (Ph. C.).	
Indiana	Purdue University	Lafayette	W. E. Stone, Ph. D	Mech. engin. (B. S., M. E.), civil engin. (B. S., C. E.), elect. engin. (B. S., E. E.), agr. (B. S. Agr.), sci. (B. S.), phar. (B. S. Phar.).	Agr. (2 yrs.), agr. (winter, 11 weeks), phar. (2 yrs., Ph. G.)
Iowa	Iowa State College of Agriculture and the Mechanic Arts.	Ames		Agr. (B. Agr.), mech. engin. (B. M. E.), civil engin. (B. C. E.), elect. engin. (B. S., E. E.), mining engin. (B. S., M. E.), sci., general and domestic sci. for women (B. S.), tech. (B. S.).	Vet. med. (3 yrs., D. V. M.), dairying (1 yr.), dairying (summer, 16 weeks), dairying (winter, 4 weeks), animal husb. (2 weeks).
Kansas	Kansas State Agricultural College.	Manhattan	E. R. Nichols, M. A	Agr., mech. engin., general sci., elect. engin., domestic sci. (B. S.).	Dairy (12 weeks), apprentice shops (80 weeks), apprentice printing (80 weeks), domestic sci., agr. and mech., hort. and mech. (24 weeks).
Kentucky	Agricultural and Mechanical College of Kentucky.	Lexington	J. K. Patterson, Ph. D., LL. D	Clas. (B. A.), mech. engin. (B. M. E.), civil engin. (B. C. E.), mining engin. (B. M. E.), agr. (B. Agr.), sci. (B. S.), pedag. (B. Ped.).	Agr. (1 yr.), agr. (10 weeks), normal.
	The Kentucky Normal and Industrial Institute for Colored Persons.	Frankfort	J. S. Hathaway, M. A., M. D.		Normal, agr., carpentry, cooking, dressmaking, printing, blacksmithing, wheelwrighting.
Louisiana	Louisiana State University and Agricultural and Mechanical College.	Baton Rouge	T. D. Boyd, M. A., LL. D	Agr., mech. engin., sugar engin., civil engin., general sci., commercial (B. S.), Lat. sci., lit. (B. A.).	
	Southern University and Agricultural and Mechanical College.	New Orleans	H. A. Hill	Clas., sci., agr., mech., normal, printing, music.	Agr., dairy, bookkeeping (2 yrs.), mech., tinsmithing (3 yrs.), typewriting.
Maine	The University of Maine	Orono	G. E. Fellows, M. A., Ph. D.	Clas. (B. A.), Lat. sci. (B. Ph.), sci. agr., chem., prep. med., phar., civil engin., mech. engin., elect. engin., mining engin. (B. S.).	Agr. (2 yrs.), agr. (1 yr.), phar. (2 yrs.), short winter courses (12 weeks).
Maryland	Maryland Agricultural College.	College Park	R. W. Silvester	Clas. (B. A.), mech. engin. (B. M. E.), agr., sci. (B. S).	Agr. (2 yrs.), agr. (10 weeks).
	Princess Anne Academy	Princess Anne	Frank Trigg, M. A	Academic	Industrial.
Massachusetts	Massachusetts Agricultural College.	Amherst	H. H. Goodell, LL. D	Agr. (B. S.), postgraduate (Ph. D.)	Agr., chem., bot., zool., fruit culture, floriculture, market gardening, animal husb., dairying (11 weeks each).

[a] Including also institutions receiving apportionments from the appropriation of 1890.

TABLE 1.—*Institutions established under the land-grant act of July 2, 1862, and their courses of study*—Continued.

State or Territory.	Name of institution.	Location.	President.	Collegiate courses of study (undergraduate).	
				Four-year courses and degrees.	Short courses.
Massachusetts	*Massachusetts Institute of Technology.	Boston	Henry S. Pritchett	Civil engin., mech. engin., mining engin. and metal., archi., chem., elect. engin., biol., phys., general studies, chem. engin., sanitary engin., geol., naval archi. (B. S.).	
Michigan	Michigan State Agricultural College.	Agricultural College.	J. L. Snyder, M. A., Ph. D.	Agr., mech., women's (B. S., each 4 and 5 years).	Cheese making (4 weeks), creamery management, fruit culture, live stock husb., (6 weeks each), beet-sugar production (20 weeks).
Minnesota	The University of Minnesota.	Minneapolis	Cyrus Northrop, LL. D	Clas. (B. A.), civil engin. (C. E.), mech. engin. (M. E.), elect. engin. (E. E.), mining, metal. (E. M., M. E.), chem. (B. S.), agr. (B. Agr.).	Agr. (3 yrs.), agr. (6 months), dairying (4 weeks), phar.
Mississippi	Mississippi Agricultural and Mechanical College.	Agricultural College.	J. C. Hardy, M. A	Agr., hort., dairying, vet. sci., chem., mech. engin., phys. and elect. engin., civil and rural engin., geol. and mining, textile (B. S.).	Agr., mech. arts, elect. engin., textile (2 yrs.), agr. (10 weeks).
	Alcorn Agricultural and Mechanical College.	Westside	W. H. Lanier, B. A	Scientific (B. S)	Business, carpentry, agr., shoemaking, blacksmithing, painting.
Missouri	College of Agriculture and Mechanic Arts of the University of Missouri.	Columbia	R. H. Jesse, LL. D.	Agr. (B. S.), civil engin. (B. S., C. E.), mech. engin., mining engin. (B. S., M. E.), elect. engin. (B. S., E. E.), sanitary engin., chem., metal., archi. (B. S.).	Agr., hort. (12 weeks).
	*School of Mines and Metallurgy of the University of Missouri.	Rolla	G. E. Ladd	Mining engin., civil engin., chem., and metal., general sci. (B. S.).	Academic, chem. and assaying, mining, surveying, elect. (2 yrs.).
	Lincoln Institute	Jefferson City	B. F. Allen, M. A	Collegiate (B. A.), normal	College prep. (3 yrs.), normal prep. (2 yrs.), carpentry, blacksmithing, mach. work (3 yrs.), sewing, cooking, laundering (3 yrs.).
Montana	The Montana College of Agriculture and Mechanic Arts.	Bozeman	James Reid, B. A	General sci., home sci. (B. S.), agr. (B. S. Agr.), chem. (B. A. C.), mech. engin. (B. M. E.), elect. engin. (B. E. E.), civil engin. (B. C. E.), biol. (B. S.), art, music.	Agr. (3 yrs.), business (1 yr.).
Nebraska	The University of Nebraska.	Lincoln	E. B. Andrews, LL. D	Clas., lit. (B. A.), general sci., agr., civil engin., elect. engin., steam engin., municipal engin., mech. engin. (B. S.).	Agr. (3 yrs.), agr. (1 yr.), mech. arts, domestic sci. (2 yrs.), dairying.

Nevada	Nevada State University	Reno	J. E. Stubbs, M. A., D. D	Liberal arts (B. A.), mining and metal., agr., domestic sci., mech. engin., civil engin., general sci., commerce (B. S.), pedag.	Agr., dairying, domestic sci., assaying, (2 months).
New Hampshire	The New Hampshire College of Agriculture and the Mechanic Arts.	Durham	C. S. Murkland, M. A., Ph. D., D. D.	Agr., biol., chem., mech. engin., elect., tech. chem., general (B. S.).	Agr. (2 yrs.), agr. (winter 10 weeks), dairying (10 weeks).
New Jersey	Rutgers Scientific School, the New Jersey State College for the benefit of Agriculture and the Mechanic Arts.	New Brunswick	Austin Scott, Ph. D., LL. D.	Agr., civil engin. and mech., chem., elect., biol., ceramics (B. S.), Lat. sci. (B. Litt.).	
New Mexico	New Mexico College of Agriculture and Mechanic Arts.	Mesilla Park	Luther Foster, M. S. A	Agr., mech. engin., civil engin., sci. (B. S.).	Agr. (2 yrs.), pract. mech. (2 yrs.), agr. and hort. (12 weeks.
New York	Cornell University	Ithaca	J. G. Schurman, M. A., D. Sc., LL. D.	Arts (B. A.), civil engin (C. E.), mech. engin. (M. E.), elect. engin. (E. E.), archi. (B. Arch.), agr. (B. S. A.), for. (B. S. F.), med. (M. D.), vet. sci. (D. V. M.).	Agr. (1 or 2 yrs.), agr., dairying (11 weeks).
North Carolina	The North Carolina College of Agriculture and Mechanic Arts.	West Raleigh	G. T. Winston, M. A., LL. D.	Agr. (B A.), mech. engin., civil engin., elect. engin., chem. engin., mining engin., textile sci. and art. (B. E.).	Agr., carpentry, mach. shops, engine and boiler tending, mach. drawing and designing (3 months), agr., mech. arts, textile indus. (2 yrs.).
	The Agricultural and Mechanical College for the Colored Race.	Greensboro	J. B. Dudley, M. A	Agr., mech. (B. S., B. Agr.)	Carpentry, blacksmithing, dairying, hort.
North Dakota	North Dakota Agricultural College.	Agricultural College.	J. H. Worst, LL. D	Agr., sci., mech. (B. S.)	Agr., farm school (2 yrs.), farm school (3 months), steam engin. (2 yrs.), (3 months), agr., dairying (12 weeks), domestic econ. (2 yrs.), (3 months), pharm. (2 yrs.)
Ohio	Ohio State University	Columbus	W. O. Thompson, D. D	Agr. (B. S. A.), hort. and for., domestic sci., sci., chem., indus. arts, manual training, phar. (B. S.), arts (B. A.), Lat. philos., modern lang. philos., Engl. philos. (Ph. B.), archi., civil engin. (C. E.), clay working and ceramics, mech. engin., mining engin., (M. E.), elect. engin. (M. E., E. E.), vet. med. (D. V. M.), law (L. B.).	Agr., hort., ceramics, domestic econ., indus. arts, mining, phar. (2 yrs.), law, journalism (3 yrs.), dairying (3 months), vet. med. (3 yrs., D. V. M.).
Oklahoma	Oklahoma Agricultural and Mechanical College.	Stillwater	A. C. Scott, M. A., LL. M	Agr., general sci. and lit., mech. engin., chem., biol. (B. S.).	Agr., hort., mech. arts (8 weeks, winter), household econ., sten. and typewriting, printing.
	Agricultural and Normal University.	Langston	I. E. Page, M. A	Clas. (B. A.), sci. (B. S.), normal (B. S. D.), agr. (B. S. Agr.), elect. engin., mech. engin., civil arch. (B. M. E.).	Normal elementary (4 yrs.), college prep. (3 yrs.).

TABLE 1.—*Institutions established under the land-grant act of July 2, 1862, and their courses of study*—Continued.

State or Territory.	Name of institution.	Location.	President.	Collegiate courses of study (undergraduate).	
				Four-year courses and degrees.	Short courses.
Oregon	Oregon State Agricultural College.	Corvallis	T. M. Gatch, M. A., Ph. D.	Agr., mech. engin., elect. engin., mining engin., household sci., phar., lit. commerce (B. S.).	Mining, business (2 yrs.), farmers' (4 weeks).
Pennsylvania	The Pennsylvania State College.	State College	G. W. Atherton, LL. D	Clas. (B. A.), general sci., Lat. sci., philos., agr., biol., chem., civil engin., elect. engin., math., mech. engin., mining engin., phys. (B. S.).	Chem., mech., mining (2 yrs.), agr., mining (12 weeks), agr., dairy, creamerymen's (8 weeks), Chautauqua.
Rhode Island	Rhode Island College of Agriculture and Mechanic Arts.	Kingston	H. J. Wheeler, Ph. D	Agr., mech. engin., chem., biol., elect. engin., general sci. (B. S.).	Poultry school (6 weeks), farm practice (6 weeks).
South Carolina	Clemson Agricultural College	Clemson College	P. H. Mell, M. E., Ph. D.	Agr., mech. and engin., textile engin. (B. S.).	Dairying (10 weeks).
	The Colored Normal, Industrial, Agricultural, and Mechanical College of South Carolina.	Orangeburg	T. E. Miller, LL. D	Regular (B. A.), mech. (B. S.), agr. (B. Agr.), normal (L. I.).	
South Dakota	South Dakota Agricultural College.	Brookings	J. W. Heston, Ph. D., LL. D.	Agr., domestic sci., mech. engin., elect. engin., hort., phar. (B. S.).	Phar. (2 yrs.) (Ph. G.), engin. drawing (24 weeks), dairy, agr., hort., domestic sci. (12 weeks), sten. and typewriting, commercial sci., steam engin. (1 yr.), art (3 yrs.), music.
Tennessee	University of Tennessee	Knoxville	C. W. Dabney, Ph. D., LL. D.	Lit. (B. A.), agr. sci., civil engin., mech. engin., elect. engin., chem. (B. S.), phar. (Ph. C.).	Phar. (2 yrs.), agr. and hort. (10 weeks).
Texas	State Agricultural and Mechanical College of Texas.	College Station	D. F. Houston	Agr., general sci., mech. engin., civil engin. (B. S.).	Stock farming, dairying, hort. (10 weeks).
	Prairieview State Normal School.	Prairieview	E. L. Blackshear	Clas. and sci. (6 yrs.) (B. A.), normal, industrial.	
Utah	Agricultural College of Utah.	Logan	W. J. Kerr, D. Sc	Agr., domestic sci., commercial, civil engin., mech. engin., elect. engin., mining engin., general sci. (B. S.), mech. arts.	Agr., domestic sci., commercial (3 yrs.), engin. prep. (2 yrs.), prep. (1 yr.), agr., domestic arts, mech. arts (10 weeks).
Vermont	University of Vermont and State Agricultural College.	Burlington	M. H. Buckham, D. D., LL. D.	Clas. (B. A.), lit. sci. (Ph. B.), civil and sanitary engin., elect. engin., mech. engin., chem., agr. (B. S.), commerce and econ. (B. A. or Ph. B.).	Agr. (1 or 2 yrs.), dairy (4 weeks).
Virginia	The Virginia Agricultural and Mechanical College and Polytechnic Institute.	Blacksburg	J. M. McBryde, Ph. D., LL. D.	Agr., hort., applied chem., general sci., civil engin., mech. engin., elect. engin. (B. S.), prep. med.	Agr., mech. (2 yrs.), dairying (4 weeks).

	The Hampton Normal and Agricultural Institute.	Hampton	H. B. Frissell, D. D., LL. D.		Academic, trade (3 yrs.). Post-graduate: Agr., trades (3 yrs.), normal (2 yrs.), business (1 yr.).
Washington	Washington Agricultural College and School of Science.	Pullman	E. A. Bryan, M. A	Math., civil engin., chem., bot. and zool., agr., hort., econ. sci. and hist., elect. engin., steam engin., hydraulic engin., mech. engin., mining engin. (B. S., B. A.), Engl. lang. and lit., modern lang. (B. A.).	Supplementary courses in phys., geol. and mineralogy, Lat., schools of phar. (2 yrs.); agr., vet. sci., prep. (3 yrs.); business (1 and 2 yrs.); artisans (1 yr.); darying (8 weeks).
West Virginia	West Virginia University	Morgantown	D. B. Purinton, Ph. D., LL. D.	General culture (B. A., B. S.), mech. engin. (B. S., M. E.), civil engin. (B. S., C. E.), steam engin., hydraulic engin., elect. engin. (B. S., M. E.), agr. (B. S. Agr.), law (LL. B.).	Agr. (B. Agr.), mech. and elect., law, commercial (2 yrs.), agr. (1 yr.), agr., vet. sci., stock breeding and feeding (12 weeks).
	The West Virginia Colored Institute.	Institute	J. McH. Jones	Academic, normal, agr., mech., printing.	Sewing (2 yrs.), dressmaking (3 yrs.).
Wisconsin	University of Wisconsin	Madison	E. A. Birge, Ph. D., D. Sc	Ancient clas. (B. A.), modern clas., civic hist., Engl. (B. L.), general sci. (B. S.), civil engin. (B. S., C. E.), mech. engin. (B. S., M. E.), elect. engin. (B. S., E. E.), agr. (B. S. Agr.), phar. (B. S. Ph.), sanitary engin., applied electro-chem.	Music, agr. (2 winter courses, 14 weeks each), dairy school (12 weeks), creamery (summer).
Wyoming	University of Wyoming	Laramie	E. E. Smiley, D. D	Clas., lit. sci. (B. A.), normal (B. Ped.), agr., mech. engin., school of mines (B. S.).	Commercial (2 yrs.), agr. (1 to 2 yrs.), normal (1 yr.), school of mines (6 weeks).

TABLE 2.—*General statistics of land-grant colleges, 1902.*

State or Territory.	Date of establishment of institution.	Date of establishment of agricultural course.	Faculty.					Graduates.				Number of volumes in library.	Number of acres allotted to State under act of 1862.	Number of acres of land-grant of 1862 still unsold.	Number of acres in farm and grounds.	Rate of interest on land-grant fund of 1862.
			College of agriculture and mechanic arts.			Other departments.	Experiment station officers.	In 1901-2.			Total number since organization.					
			Preparatory classes.	Collegiate and special classes	Total.			Number.	Average age.							
									Y.	*M.*						*Per ct.*
Alabama (Auburn)	1872	1872	3	21	24	....	13	36	20	9	684	18,417	240,000	....	323	8
Alabama (Normal)	1875	1882	8	12	*a* 15	11	....	70	18		672	3,735	....	....	182	....
Arizona	1891	1891	13	12	*a* 16	....	8	9	22		28	16,828	....	....	113	....
Arkansas (Fayetteville)	1872	1872	20	22	*a* 28	6	6	23	22	4	298	16,049	150,000	....	160	8
Arkansas (Pine Bluff)	1875	....	3	5	8	....	....	5	23		155	4,627	....	....	20	....
California	1868	1868	....	85	*a* 85	127	31	456	23	4	*b* 2,830	148,000	150,000	4,194	411	6
Colorado	1877	1878	10	32	*a* 32	....	15	31	....		212	23,900	90,000	44,685	600	6
Connecticut	1881	1881	....	20	20	....	14	11	20	4	207	10,208	180,000	....	300	5
Delaware (Newark)	1870	1870	....	19	19	....	6	15	22	3	399	22,000	90,000	....	14	6
Delaware (Dover)	1892	1892	3	3	6	....	....	5	21		18	700	....	....	97	....
Florida (Lake City)	1884	1884	2	17	19	....	13	6	20	6	75	4,000	90,000	....	393	6
Florida (Tallahassee)	1887	1890	9	7	16	....	....	8	23		35	1,778	....	....	200	....
Georgia (Athens)	1872	1872	....	21	21	....	7	7	21		371	41,660	270,000	....	128	7
Georgia (College)	1890	1890	16	5	*a* 14	....	....	43	20		101	700	....	....	86	....
Idaho	1892	1892	5	14	19	2	8	11	26	6	68	6,550	90,000	90,000	115	....
Illinois	1867	1868	....	72	72	225	22	*b* 489	23	6	*b* 2,890	73,000	480,000	40	665	5
Indiana	1874	1874	....	78	78	3	10	166	22	8	1,477	14,411	390,000	....	189	5
Iowa	1869	1869	....	....	69	....	21	67	23		1,177	18,500	204,000	1,336	841	6, 7, 8
Kansas	1863	1874	12	51	63	....	17	43	24		865	26,025	82,314	....	323	5, 5½, 6, 7
Kentucky (Lexington)	1865	1880	5	31	36	....	16	58	21	7	290	15,800	330,000	....	258	6
Kentucky (Frankfort)	1887	1892	2	5	7	3	....	5	20		100	2,564	....	....	310	....
Louisiana (Baton Rouge)	1877	1887	7	23	*a* 27	....	26	35	20	6	293	23,000	210,000	....	583	4, 5
Louisiana (New Orleans)	1880	1890	8	8	16	....	....	32	17	6	215	4,189	....	....	104	....
Maine	1865	1868	....	44	44	10	12	50	22	11	768	29,169	210,000	....	373	5
Maryland (College Park)	1859	1859	1	16	17	17	15	10	20		....	6,100	210,000	....	286	5, 6
Maryland (Princess Anne)	....	....	6	....	6	....	....	9	20		....	....	....	....	120	....
Massachusetts (Amherst)	1867	1867	....	21	21	....	19	23	22	9	586	22,000	360,000	....	425	5
Massachusetts (Boston)	1865	....	....	113	113	76	....	195	22	5	2,701	73,561	....	....	15	....
Michigan	1855	1855	....	60	60	....	14	59	23	7	911	23,076	235,682	61,553	684	7
Minnesota	1869	1869	....	....	87	187	14	*b* 437	....		*b* 4,127	110,000	94,000	80	300	3, 4, 5
Mississippi (Agricultural College)	1880	1880	6	21	27	11	10	21	20	5	303	18,208	207,920	....	2,001	6
Mississippi (Westside)	1871	1878	10	6	16	....	....	6	25		133	7,200	....	....	300	5
Missouri (Columbia)	1870	1870	....	58	58	105	16	31	....		2,126	81,000	277,016	47,107	694	5
Missouri (Rolla)	1870	....	....	....	25	....	....	15	25		147	7,500	....	....	27	....
Missouri (Jefferson City)	1865	1866	....	1	1	15	....	33	21		192	700	....	....	45	....

Montana	1893	1893	2	25	*a* 26	....	9	8	22		23	11,348	90,000	90,000	215	....
Nebraska	1869	1869	....	78	78	....	17	*b* 221	....		*b* 1,875	53,080	90,000	12,000	332	4½, 6
Nevada	1873	1888	9	18	*a* 23	....	10	19	21		192	16,475	90,000	....	95	4
New Hampshire	1866	1866	....	19	19	....	11	9	23		238	15,935	150,000	....	343	6
New Jersey	1864	1865	12	26	38	3	7	36	22	2	448	49,520	210,000	....	105	5
New Mexico	1889	1890	4	17	21	....	11	5	20	4	37	13,150	....	....	270	....
New York	1865	1865	....	....	....	....	18	*b* 496	....		*b* 6,520	304,852	989,920	....	270	5
North Carolina (West Raleigh)	1889	1889	....	30	30	....	12	14	21	7	175	5,200	270,000	....	593	6
North Carolina (Greensboro)	1891	1891	....	9	9	9	....	7	....		24	877	....	....	125	....
North Dakota	1890	1890	10	21	*a* 27	....	7	4	22		31	9,100	130,000	119,790	640	....
Ohio	1870	1873	....	65	65	73	....	141	21		1,381	52,000	630,000	....	345	6
Oklahoma (Stillwater)	1891	1892	3	18	21	....	9	18	21	6	53	15,070	....	....	200	....
Oklahoma (Langston)	1897	1899	9	....	9	....	....	....	....		....	750	....	....	160	....
Oregon	1868	1888	....	30	30	....	11	32	....		437	3,270	90,000	....	199	6
Pennsylvania	1855	1859	6	18	*a* 48	....	14	30	23	4	582	18,557	780,000	....	400	6
Rhode Island	1888	1890	8	24	*a* 24	....	11	4	21		95	14,029	120,000	....	178	3
South Carolina (Clemson College)	1889	1893	8	38	*a* 40	....	17	59	21	6	198	8,867	....	....	1,102	6
South Carolina (Orangeburg)	1896	1896	10	5	15	12	....	58	19		174	1,259	....	....	130	....
South Dakota	1881	1884	3	23	26	....	12	24	23		215	17,626	160,000	160,000	400	....
Tennessee	1794	1869	....	39	39	42	11	90	21		....	25,300	300,000	....	230	6
Texas (College Station)	1871	1871	....	28	28	....	14	28	21		423	9,500	180,000	....	2,416	6, 7
Texas (Prairieview)	....	....	23	5	*a* 23	....	....	14	24		261	1,200	....	....	1,500	....
Utah	1888	1889	9	26	35	....	15	3	24		88	21,500	200,000	200,000	116	....
Vermont	1865	1885	....	38	38	31	11	88	23	5	3,636	95,605	150,000	....	150	6
Virginia (Blacksburg)	1872	1872	....	34	34	....	11	51	23		380	5,000	220,000	....	404	6
Virginia (Hampton)	1865	1890	....	73	73	....	....	43	21		1,152	11,568	110,000	....	795	....
Washington	1892	1892	10	40	50	....	14	38	25		98	9,385	90,000	90,000	250	....
West Virginia (Morgantown)	1867	1867	18	31	49	....	15	59	23		831	20,000	90,000	....	130	6
West Virginia (Institute)	1891	1892	6	7	13	....	....	18	20		....	2,190	....	....	69	....
Wisconsin	1848	1866	34	66	100	78	17	302	21		4,908	86,239	240,000	80	400	4
Wyoming	1887	1891	13	13	*a* 13	4	8	4	22	6	97	22,000	90,000	90,000	416	....
Total	....	....	346	1,797	2,229	1,050	625	4,443	21	11	50,026	1,795,607	10,110,852	1,010,845	24,663	....

a Total, counting none twice.

b Including all departments of the university.

TABLE 3.—*Students, by classes and courses, at land-grant colleges in 1902.*

State or Territory.	By classes.						By courses.										
	Preparatory classes.	Collegiate classes.	Short or special.	Postgraduate.	Other departments.	Total.	Agriculture.	Mechanical engineering.	Civil engineering.	Electrical engineering.	Mining engineering.	Chemical engineering.	Architecture.	Household economy.	Veterinary science.	Dairying.	Military tactics.
Alabama (Auburn)	58	326	....	22	....	406	97	55	29	57	....	....	....	....	17	....	278
Alabama (Normal)	142	170	84	59	....	455	158	....	....	....	....	....	....	244	....	20	211
Arizona	142	69	....	4	....	215	....	2	4	....	40	....	....	13	....	....	112
Arkansas (Fayetteville)	114	58	22	3	412	609	10	11	42	32	....	....	....	....	....	....	358
Arkansas (Pine Bluff)	180	50	15	....	....	245	....	6	....	2	....	....	....	....	....	....	....
California	....	761	37	17	2,377	3,192	61	a 190	91	....	248	171	....	....	....	....	779
Colorado	130	181	131	6	....	418	47	97	19	....	....	....	9	80	9	18	300
Connecticut	....	50	30	2	....	82	62	....	....	....	....	....	....	12	....	5	45
Delaware (Newark)	....	109	1	4	....	114	8	7	28	21	....	....	....	....	8	6	97
Delaware (Dover)	45	28	....	....	....	73	....	....	3	....	....	....	....	20	....	....	....
Florida (Lake City)	66	69	65	....	....	200	41	84	22	....	....	....	....	....	....	1	134
Florida (Tallahassee)	153	....	....	....	....	153	22	....	....	....	....	....	8	45	....	22	....
Georgia (Athens)	....	132	20	2	....	154	43	....	12	8	....	....	5	....	....	....	132
Georgia (College)	218	159	....	....	....	377	12	....	....	....	....	....	....	....	....	....	....
Idaho	134	121	....	....	51	306	....	....	15	....	28	....	....	....	....	....	125
Illinois	....	519	160	27	2,226	2,932	203	131	170	105	....	5	62	37	68	48	594
Indiana	....	950	189	18	....	1,187	120	321	206	272	....	....	....	20	66	26	419
Iowa	250	960	300	10	....	1,520	194	91	119	163	15	....	....	90	56	81	550
Kansas	298	787	338	32	....	1,396	341	233	....	....	....	....	....	296	....	66	....
Kentucky (Lexington)	110	379	105	17	....	611	6	137	46	....	....	....	....	....	....	....	489
Kentucky (Frankfort)	101	38	52	27	....	218	22	2	....	....	....	....	1	17	....	3	....
Louisiana (Baton Rouge)	162	254	3	1	....	420	37	34	40	....	....	....	....	....	17	....	347
Louisiana (New Orleans)	409	6	472	....	....	b 422	39	....	....	....	....	....	6	....	....	25	....
Maine	....	345	14	5	47	411	18	31	112	91	....	....	....	....	....	16	279
Maryland (College Park)	30	104	19	....	....	153	19	44	2	....	....	....	....	....	6	5	143
Maryland (Princess Anne)	80	....	3	....	....	83	20	....	....	....	....	....	....	23	....	....	....
Massachusetts (Amherst)	....	172	38	14	....	224	224	....	3	....	....	....	....	....	9	36	183
Massachusetts (Boston)	....	1,399	....	16	....	1,415	....	129	102	96	76	30	40	....	....	....	385
Michigan	72	527	94	7	....	b 689	293	249	....	....	....	....	....	158	80	70	400
Minnesota	c 497	475	156	2	2,582	b 3,655	619	90	100	95	109	21	....	....	....	114	550
Mississippi (Agricultural College)	250	322	28	4	....	b 564	478	227	....	10	....	....	....	....	214	241	....
Mississippi (Westside)	437	42	....	....	....	479	150	....	....	....	....	....	....	....	....	....	....
Missouri (Columbia)	....	263	130	12	1,073	1,478	145	34	98	62	139	19	....	26	40	24	251
Missouri (Rolla)	....	185	....	8	....	193	....	....	12	1	....	156	....	....	....	....	....
Missouri (Jefferson City)	....	46	....	....	207	253	46	....	....	....	....	....	....	....	....	....	....

Montana	97	72	38	2	67	276	24	1	6	6	12	....	....	12	....	....	55
Nebraska	98	....	59	....	2,132	2,289	11	34	58	86	....	....	....	21	....	....	300
Nevada	128	203	3	3	....	*b* 334	1	17	2	....	53	....	....	25	....	....	170
New Hampshire	....	131	43	....	....	*b* 131	51	29	....	12	....	8	....	....	19	12	86
New Jersey	155	157	4	2	61	379	57	....	43	29	....	19	....	....	....	....	159
New Mexico	120	27	66	2	....	215	3	22	....	....	....	....	....	....	....	....	....
New York	....	829	55	27	1,934	2,845	92	792	214	....	....	....	50	....	51	....	....
North Carolina (West Raleigh)	....	325	41	3	....	369	72	155	32	58	....	11	41	....	....	....	....
North Carolina (Greensboro)	....	91	....	....	....	91	40	41	....	....	....	....	10	....	40	40	....
North Dakota	77	25	538	2	....	642	370	191	....	....	....	....	....	125	78	41	96
Ohio	....	669	112	2	733	1,516	49	71	79	63	35	20	8	39	64	40	400
Oklahoma (Stillwater)	188	161	85	1	....	435	40	53	....	5	....	....	....	67	....	....	....
Oklahoma (Langston)	211	....	....	....	....	211	83	83	....	....	....	....	....	128	....	....	....
Oregon	38	398	42	10	30	518	64	106	....	11	107	....	....	90	9	64	321
Pennsylvania	37	417	46	4	....	504	13	100	78	128	26	....	....	....	....	43	425
Rhode Island	51	37	42	5	....	135	6	6	2	8	....	3	....	....	....	....	65
South Carolina (Clemson College)	100	393	....	7	....	500	43	88	8	80	....	....	....	....	23	11	156
South Carolina (Orangeburg)	554	70	....	....	....	624	150	65	....	....	....	....	80	230	....	25	300
South Dakota	124	190	263	3	....	580	43	37	....	8	....	....	4	33	6	27	164
Tennessee	....	333	47	3	235	618	46	*d* 90	....	....	....	....	....	....	24	24	199
Texas (College Station)	....	464	....	3	....	467	206	115	98	....	....	....	....	....	32	....	464
Texas (Prairieview)	321	9	5	....	....	335	40	45	....	1	....	....	12	178	....	....	....
Utah	302	146	68	....	....	516	22	3	57	....	....	....	....	74	9	9	205
Vermont	....	289	63	3	215	570	40	19	37	32	....	36	....	....	20	52	200
Virginia (Blacksburg)	....	380	72	20	....	472	35	135	50	150	....	....	....	....	10	12	142
Virginia (Hampton)	1,079	....	....	....	....	1,079	666	....	....	....	....	....	....	520	....	....	395
Washington	230	154	375	3	....	*b* 724	6	*d* 32	14	....	24	....	....	....	....	8	281
West Virginia (Morgantown)	222	533	117	29	....	901	37	*e* 79	....	....	....	....	....	....	....	....	144
West Virginia (Institute)	42	103	....	....	....	145	7	....	....	....	....	....	....	83	2	7	62
Wisconsin	....	535	424	....	1,818	2,777	*f* 446	64	93	116	....	....	....	....	....	130	671
Wyoming	20	15	....	....	134	169	1	11	....	....	23	....	....	....	....	....	75
Total	8,272	17,212	5,114	483	16,334	46,699	6,299	4,702	2,146	1,814	935	499	336	2,706	977	1,372	12,996

[a] Including electrical.
[b] Total, counting none twice.
[c] Including 441 students in School of Agriculture.
[d] Including civil and electrical engineering.
[e] Including civil, electrical, and mining engineering.
[f] Including dairying.

TABLE 4.—*Value of permanent funds and equipment of land-grant colleges, 1902.*

State or Territory.	Land-grant fund of 1862.	Other land-grant funds.	Other permanent funds.	Land grant of 1862 still unsold.	Farm and grounds owned by the institution.	Buildings.	Apparatus.	Machinery.	Library.	Miscellaneous equipment.	Total.
Alabama (Auburn)	$253,500.00				$4,500.00	$143,807.00	$13,200.00	$16,800.00	$31,807.50	$17,000.00	$480,614.50
Alabama (Normal)					18,200.00	42,803.54	5,079.34	3,116.73	2,957.00		72,156.61
Arizona					20,640.00	113,433.89	17,095.14	12,782.56	12,273.01	52,701.19	228,925.79
Arkansas (Fayetteville)	130,000.00				16,000.00	246,000.00	29,000.00	15,000.00	11,500.00	5,500.00	453,000.00
Arkansas (Pine Bluff)					50,000.00	26,000.00	500.00	14,000.00		1,500.00	92,000.00
California	730,965.54	$74,962.27	$2,229,100.15	$10,486.18	193,125.00	760,000.00				[a] 390,000.00	4,388,639.14
Colorado	89,519.50			150,000.00	46,000.00	151,849.00	46,000.00	15,500.00	18,750.00	15,500.00	533,118.50
Connecticut	135,000.00				15,000.00	112,000.00	7,500.00	6,800.00	21,000.00	12,000.00	309,300.00
Delaware (Newark)	83,000.00				3,000.00	110,000.00	50,000.00	5,000.00	20,000.00	8,000.00	279,000.00
Delaware (Dover)					6,000.00	18,800.00	1,000.00	8,000.00			33,800.00
Florida (Lake City)	154,300.00				18,000.00	100,000.00		22,000.00	8,000.00		302,300.00
Florida (Tallahassee)					5,500.00	25,000.00	1,000.00	2,000.00	1,000.00	5,500.00	40,000.00
Georgia (Athens)	243,000.00				15,000.00	340,000.00	50,000.00	10,000.00	50,000.00	390,000.00	1,098,000.00
Georgia (College)					1,400.00	32,433.04				3,144.00	36,977.04
Idaho					14,000.00	175,000.00	16,200.00	3,200.00	10,625.00	2,500.00	221,525.00
Illinois	597,220.53		1,250.00	600.00	150,000.00	1,175,000.00	160,000.00	60,000.00	80,000.00	110,000.00	2,334,070.53
Indiana	340,000.00				60,000.00	384,000.00				[a] 312,000.00	1,096,000.00
Iowa	589,754.01	93,954.51		6,214.08	60,000.00	500,000.00	73,000.00	30,000.00	29,000.00	115,000.00	1,496,922.60
Kansas	491,181.36				39,700.00	306,187.00	35,742.76	16,582.38	45,279.97	148,373.17	1,083,046.64
Kentucky (Lexington)	165,000.00				310,000.00	161,000.00	43,400.00	24,200.00	10,600.00	417,000.00	1,131,200.00
Kentucky (Frankfort)					22,600.00	23,000.00	350.00	2,500.00	1,700.00	1,200.00	51,350.00
Louisiana (Baton Rouge)	182,313.00	136,000.00	691,280.00		33,300.00	200,000.00	13,000.00	9,000.00	25,000.00	26,000.00	1,315,893.00
Louisiana (New Orleans)					22,000.00	46,364.82	3,429.20	4,384.00	3,948.00	7,389.16	87,515.18
Maine	118,300.00		101,600.00		25,000.00	222,241.00	22,000.00	16,000.00	24,500.00	12,500.00	542,141.00
Maryland (College Park)	118,000.00				28,600.00	90,000.00				[a] 32,000.00	268,600.00
Maryland (Princess Anne)					4,000.00	[b] 12,000.00					16,000.00
Massachusetts (Amherst)	219,000.00		141,575.35		42,500.00	213,775.00	17,600.00		22,473.00	70,000.00	726,923.35
Massachusetts (Boston)			3,435,717.34			717,038.74	250,000.00	91,140.00	123,347.00		4,617,243.08
Michigan	915,454.43		[c] 100,000.00	200,000.00	48,107.50	359,725.00	32,054.24	16,003.05	41,980.05	101,585.44	1,814,909.71
Minnesota	570,335.59		763,699.96	240.00	550,000.00	1,070,500.00	97,500.00	77,000.00	85,000.00		3,214,275.55
Mississippi (Agricultural College)	98,575.00	141,212.55			43,500.00	180,480.00	15,204.33	82,311.73	15,644.46	61,195.15	638,123.22
Mississippi (Westside)	113,575.00	96,296.00			3,000.00	150,000.00	10,000.00	5,000.00	5,000.00	2,000.00	384,871.00
Missouri (Columbia)	349,881.19			60,000.00	237,206.00	250,000.00				[a] 105,000.00	1,002,087.19
Missouri (Rolla)					15,000.00	170,000.00		[d] 29,900.00	9,000.00	13,000.00	236,900.00
Missouri (Jefferson City)					5,000.00	100,000.00					105,000.00
Montana		19,000.00		900,000.00	12,000.00	110,000.00	15,000.00	15,000.00	15,000.00		1,086,000.00
Nebraska	215,348.07	98,614.04			325,000.00	469,000.00		[d] 225,376.00	106,160.00	23,000.00	1,462,498.11
Nevada	93,000.00	36,000.00			33,747.90	164,213.25	18,763.50	11,485.56	14,176.95	35,377.19	406,764.35
New Hampshire	80,000.00				20,500.00	84,016.21	15,903.20	5,464.00	9,800.00	20,000.00	235,683.44
New Jersey	116,000.00		500,000.00		130,000.00	366,500.00			40,000.00	75,000.00	1,227,500.00
New Mexico					7,500.00	45,000.00	16,500.00	19,000.00	12,500.00	7,500.00	108,000.00
New York	688,576.12		6,559,391.50		99,218.91	2,724,372.86			528,384.40	742,332.86	11,342,276.65

North Carolina (West Raleigh)	125,000.00				26,189.55	113,785.29	11,822.08	34,874.38	5,832.20	10,000.00	327,503.50
North Carolina (Greensboro)					10,000.00	42,300.00			1,000.00		53,300.00
North Dakota	22,318.81			1,197,905.80	32,000.00	154,000.00	12,000.00	10,000.00	16,000.00		1,444,224.61
Ohio	524,176.30	34,380.47	c 193,385.25		1,500,000.00	842,733.18	176,000.00	37,000.00	75,000.00	27,000.00	3,409,675.20
Oklahoma (Stillwater)		14,730.49			10,000.00	98,500.00	30,800.00	22,928.83	17,964.90	7,000.00	201,924.22
Oklahoma (Langston)					5,000.00	33,904.35	1,500.00	8,500.00	1,600.00	2,500.00	53,004.35
Oregon	131,556.37				20,000.00	120,000.00	3,500.00	17,000.00			292,056.37
Pennsylvania	427,290.50		25,000.00		40,000.00	750,000.00				60,000.00	1,302,290.50
Rhode Island	50,000.00				18,000.00	200,000.00			13,678.90	101,060.86	382,739.76
South Carolina (Clemson College)	95,900.00		80,000.00		26,280.00	323,000.00	120,000.00	70,000.00	7,000.00	15,000.00	737,180.00
South Carolina (Orangeburg)	95,900.00				40,000.00	80,000.00	3,600.00	7,150.00	1,500.00	2,000.00	230,150.00
South Dakota				800,000.00	40,000.00	170,000.00	11,000.00	3,200.00	5,300.00		1,029,500.00
Tennessee	396,000.00		29,000.00		106,370.00	205,408.66	47,491.92	44,915.00	11,000.00	11,700.91	851,886.49
Texas (College Station)	209,000.00				48,320.00	400,000.00	10,842.34	22,578.08	5,500.00	35,624.16	731,864.58
Texas (Prairieview)					20,000.00	81,200.00	800.00	2,500.00	1,320.00	3,600.00	109,420.00
Utah		101,670.00			12,800.00	205,492.71	9,928.07	1,520.98	6,548.35	24,904.71	362,864.82
Vermont	135,500.00		448,550.00		30,000.00	575,000.00	58,000.00	10,000.00	150,000.00	20,000.00	1,427,050.00
Virginia (Blacksburg)	344,312.00				30,000.00	218,740.03			2,600.00	111,955.80	707,607.83
Virginia (Hampton)	516,468.00		1,055,321.00		57,000.00	565,000.00			6,000.00	e 155,500.00	2,355,289.00
Washington				900,000.00	15,000.00	250,000.00	20,000.00	35,000.00	20,000.00	15,000.00	1,255,000.00
West Virginia (Morgantown)	90,000.00				225,000.00	450,000.00	10,000.00	20,000.00	40,000.00		835,000.00
West Virginia (Institute)					12,000.00	82,200.00	8,000.00	16,000.00	3,000.00		121,200.00
Wisconsin	303,359.61	228,263.95		100.00	110,173.00	1,279,806.00		d 280,795.00	130,293.00		2,332,790.56
Wyoming	21,450.57	4,064.71		90,000.00	10,600.00	150,000.00	59,000.00	27,000.00	21,800.00	6,300.00	390,215.28
Total	11,369,031.50	1,079,148.99	16,354,870.55	4,315,546.06	5,198,577.86	20,082,610.60	1,670,306.12	1,545,508.28	1,979,343.69	3,949,944.60	67,544,888.25

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[a] Including apparatus, machinery, and library.

[b] Including apparatus and machinery.

[c] From mill tax.

[d] Including apparatus.

[e] Including machinery.

TABLE 5.—*Revenue of land-grant colleges for year ended June 30, 1902.*

State or Territory.	Federal aid.			State aid.			Income from endowment other than Federal or State grants.	Fees and all other sources.			Total income.	United States appropriation for experiment stations (act of 1887).
	Interest on land grant of 1862.	Interest on other land grants.	Appropriation act of 1890.	Interest on endowment or regular appropriation.	Appropriation for current expenses.	Appropriations for buildings or for other special purposes.		Tuition fees.	Incidental fees.	Miscellaneous.		
Alabama (Auburn)	$20,280.00		$13,850.00	$12,872.84				$920.00	$1,850.00	$4,623.57	$54,396.41	$15,000.00
Alabama (Normal)			11,150.00		$4,000.00					15,655.80	30,805.80	
Arizona			25,000.00		20,877.39				1,491.35	2,459.50	49,828.24	15,000.00
Arkansas (Fayetteville)	10,400.00		18,181.82		38,150.00	$15,450.00		420.00	2,880.00	1,344.66	86,826.48	15,000.00
Arkansas (Pine Bluff)			6,818.18					375.00	52.00		7,245.18	
California	43,870.00	$1,440.00	25,000.00	65,679.61	100,000.00	246,754.30	$44,196.99	12,847.45	51,318.68		594,107.03	15,000.00
Colorado	10,851.76		25,000.00		51,066.38	8,000.00				5,820.52	100,738.66	15,000.00
Connecticut	6,700.00		25,000.00		15,000.00	1,800.00				16,000.00	64,500.00	7,500.00
Delaware (Newark)	4,980.00		20,000.00			17,500.00		60.00	1,750.00	3,579.24	47,869.24	15,000.00
Delaware (Dover)			5,000.00			3,000.00				2,227.78	10,227.78	
Florida (Lake City)	8,955.51		12,500.00			61,250.00			[a]2,336.16	1,271.17	86,312.84	15,000.00
Florida (Tallahassee)			12,500.00		4,500.00						17,000,00	
Georgia (Athens)	16,954.14		16,666.66						527.50	256.62	34,404.92	15,000.00
Georgia (College)			8,333.34		8,000.00						16,333.34	
Idaho			25,000.00		10,000.00	1,000.00			300.00	965.75	37,265.75	15,000.00
Illinois	32,176.96		25,000.00		175,000.00	346,330.01			[a]156,891.82	28,391.15	763,789.94	15,000.00
Indiana	17,000.00		25,000.00		66,900.00	21,849.71		2,287.50	29,549.30	21,882.28	184,468.79	15,000.00
Iowa	38,253.93		25,000.00		25,000.00	113,088.77			335.00	2,517.30	204,195.00	15,000.00
Kansas	25,370.00		25,000.00		25,000.00	99,880.00					175,250.00	15,000.00
Kentucky (Lexington)	8,644.50		21,375.00	36,578.11		18,500.00		2,377.40	1,210.75	32,566.49	121,252.25	15,000.00
Kentucky (Frankfort)	1,255.50		3,625.00		3,000.00				196.00	1,907.26	9,983.76	
Louisiana (Baton Rouge)	9,115.69	5,440.00	12,106.85		15,000.00	6,000.00			2,097.50	5,261.60	55,021.64	15,000.00
Louisiana (New Orleans)			12,893.15		10,000.00			167.00	77.00	400.00	23,537.15	
Maine	5,915.00		25,000.00		15,000.00			12,870.00	8,580.00	23,315.63	90,680.63	15,000.00
Maryland (College Park)	3,478.30		20,969.33		9,000.00	12,000.00		[b]16,313.02	7,353.10	1,058.19	70,171.94	15,000.00
Maryland (Princess Anne)			4,030.67					577.24	6.00	673.91	5,287.82	
Massachusetts (Amherst)	7,300.00		16,666.66	3,703.34	13,000.00	8,500.00			730.00	1,775.37	51,675.37	15,000.00
Massachusetts (Boston)	5,468.34		8,333.34		25,000.00		65,000.00	221,583.00	10,844.99	31,603.99	367,833.66	
Michigan	65,000.00		25,000.00	100,000.00		14,200.00		385.00	4,230.00	44,072.28	252,887.28	15,000.00
Minnesota	23,452.00		25,000.00	30,161.30	184,030.69	222,150.00		104,000.00		27,732.66	616,526.65	15,000.00
Mississippi (Agricultural College).	5,914.50	8,358.00	11,624.16		48,272.41	81,330.00		330.00	1,625.00	24,386.95	181,841.02	15,000.00
Mississippi (Westside)	6,814.50	5,777.77	13,375.84		8,000.00	23,000.00				800.00	57,768.11	
Missouri (Columbia)	13,121.10		17,550.50		22,500.00	36,873.07			5,353.60	11,057.77	106,456.04	15,000.00
Missouri (Rolla)	4,373.00	100.00	5,887.00	6,599.58	16,000.00	87,000.00			3,500.00		123,459.58	
Missouri (Jefferson City)			1,562.50		1,000.00						2,562.50	
Montana	9,300.00		25,000.00		12,000.00	15,000.00		2,251.00	750.00	4,694.28	68,995.28	15,000.00
Nebraska	35,000.00	20,000.00	25,000.00	82,500.00	37,250.00					[c]32,216.61	231,966.61	15,000.00

Nevada			25,000.00		18,000.00	15,500.00				598.49	59,098.49	15,000.00
New Hampshire	4,800.00		25,000.00		8,000.00	17,500.00		1,038.84	592.50	28,301.82	85,233.16	15,000.00
New Jersey	6,480.00		25,000.00				18,388.81		[a] 6,507.02	423.65	56,799.48	15,000.00
New Mexico			25,000.00		5,509.80			1,178.50	5.15	1,453.92	33,147.37	15,000.00
New York	34,428.80		25,000.00				372,684.05	237,030.33	48,254.34	388,131.64	1,105,529.16	13,500.00
North Carolina (West Raleigh)	7,500.00		16,750.00	10,000.00		27,260.81		5,645.51	3,313.18	10,245.54	80,715.04	15,000.00
North Carolina (Greensboro)			8,250.00		7,500.00	5,000.00		286.21		4,884.97	25,921.18	
North Dakota	3,578.40		25,000.00		25,000.00					55,859.69	109,438.09	15,000.00
Ohio	31,450.64	2,155.37	25,000.00	193,385.25		64,997.05		7,392.50	30,567.50	65,058.09	420,006.40	
Oklahoma (Stillwater)		14,730.49	22,500.00		5,137.14	48,128.81			975.14	3,465.50	94,937.08	15,000.00
Oklahoma (Langston)			2,500.00		18,000.00	3,000.00				219.20	23,719.20	
Oregon	10,362.85		25,000.00		5,000.00	25,954.17			711.00	1,782.10	68,810.12	15,000.00
Pennsylvania	25,637.43		25,000.00	5,382.57	42,228.87	1,750.00		150.00	6,737.75	16,105.44	122,992.06	15,000.00
Rhode Island	2,500.00		25,000.00		15,000.00	5,195.00			420.00		48,115.00	15,000.00
South Carolina (Clemson College)	5,754.00		12,500.00		85,670.83		3,512.36	2,816.97	924.61	5,366.18	116,544.95	15,000.00
South Carolina (Orangeburg)	5,754.00		12,500.00			8,500.00					26,754.00	
South Dakota			25,000.00		24,700.00	50,000.00		3,854.00	2,290.00	12,970.32	118,634.32	14,500.00
Tennessee	23,960.00		25,000.00				3,606.00		12,760.15	6,522.46	71,848.61	15,000.00
Texas (College Station)	14,280.00		18,750.00		25,000.00	42,000.00					100,030.00	15,000.00
Texas (Prairieview)			6,250.00		18,000.00	4,700.00				[d] 11,659.21	40,609.21	
Utah	4,997.59		25,000.00		21,000.00	66,100.00		2,383.50		6,653.52	126,134.61	15,000.00
Vermont	8,130.00		25,000.00		6,000.00		23,699.07		[a] 16,056.07	3,607.78	82,492.92	15,000.00
Virginia (Blacksburg)	20,658.72		16,666.67		25,000.00	25,000.00		585.00	13,123.36	1,033.00	102,066.75	15,000.00
Virginia (Hampton)	10,329.36		8,333.33				50,349.80		497.25	116,371.59	185,881.33	
Washington			25,000.00		30,000.00	21,000.00		30.00	6,092.48	6,522.83	88,645.31	15,000.00
West Virginia (Morgantown)	6,543.00		20,000.00		47,250.00	109,300.00			[a] 10,303.15	9,728.06	203,124.21	15,000.00
West Virginia (Institute)			5,000.00		1,000.00				125.00	289.00	6,414.00	
Wisconsin	13,331.00	11,097.00	25,000.00		289,000.00	65,000.00	726.00	24,000.00	43,500.00	42,675.00	514,329.00	15,000.00
Wyoming	2,540.13		25,000.00	5,500.48	10,406.00				473.50	908.97	44,829.08	15,000.00
Total	682,960.65	72,098.63	1,200,000.00	552,363.08	1,694,949.51	2,066,341.70	582,163.08	664,154.97	500,064.90	1,151,176.30	9,166,272.82	695,500.00

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[a] Including tuition fees.

[b] Including board of students.

[c] Including tuition and incidental fees.

[d] Including fees and board.

TABLE 6.—*Additions to equipment of land-grant colleges, 1902.*

State or Territory.	Permanent endowment.	Buildings.	Library.	Apparatus.	Machinery.	Miscellaneous.	Total.
Alabama (Auburn)		$1,276.40	$1,807.50	$1,200.00	$1,800.00		$6,083.90
Alabama (Normal)							
Arizona		7,033.89	1,248.29	2,060.70	2,441.41	$453.94	13,238.26
Arkansas (Fayetteville)		14,000.00	600.00	3,500.00	1,100.00	500.00	19,700.00
Arkansas (Pine Bluff)		5,800.00			2,000.00	100.00	7,900.00
California	$107,500.00	*a* 64,999.82	19,691.66			*b* 15,000.00	207,191.48
Colorado			500.00	1,850.00		650.00	3,000.00
Connecticut			973.20	1,020.13	3,360.36	3,832.22	9,185.91
Delaware (Newark)		12,500.00	1,400.00	1,450.00	1,200.00	2,475.00	19,025.00
Delaware (Dover)		6,000.00					6,000.00
Florida (Lake City)		50,000.00	143.67	323.02	1,000.00	4,130.06	55,596.75
Florida (Tallahassee)		2,500.00					2,500.00
Georgia (Athens)			850.00	600.00			1,450.00
Georgia (College)		3,855.28					3,855.28
Idaho		50,000 00	125.00	1,200.00	200.00	125.00	51,950.00
Illinois	35,325.40	175,000.00	10,000.00	5,000.00	5,000.00	5,000.00	235,325.40
Indiana		22,000.00	275.00	2,000.00	2,475.00	250.00	27,000.00
Iowa		100,000.00	2,000.00	2,000.00	1,000.00		105,000.00
Kansas		75,000.00	1,500.00	840.00	1,370.00	7,000.00	85,710.00
Kentucky (Lexington)		20,000.00	1,170.91	3,247.82	673.06	400.00	25,191.79
Kentucky (Frankfort)			125.00	12.00	100.00		237.00
Louisiana (Baton Rouge)		17,812.18	681.91	1,505.13	1,270.61	690.80	21,960.63
Louisiana (New Orleans)			28.00	92.50		343.00	163.50
Maine			2,250.91	3,756.00	2,000.00	75.00	8,081.94
Maryland (College Park)							
Maryland (Princess Anne)							
Massachusetts (Amherst)			1,000.00	625.00			1,625.00
Massachusetts (Boston)	116,658.04		6,615.00				123,303.04
Michigan	100,000.00						100,000.00
Minnesota	19,782.72	161,700.00	8,500.00	11,461.00	30,000.00		231,443.72
Mississippi (Agricultural College)		1,886.28	783.64	1,287.83	33,441.51	9,971.00	47,373.26
Mississippi (Westside)		150,000.00	5,000.00	1,200.00	5,000.00	2,500.00	163,700.00
Missouri (Columbia)							
Missouri (Rolla)	25,000.00	94,000.00	800.00	3,000.00			122,800.00
Missouri (Jefferson City)		1,000.00					1,000.00
Montana		16,000.00	2,000.00	1,250.00	950.00		20,200.00
Nebraska			8,450.00		*c* 7,500.00	1,500.00	17,450.00
Nevada	1,599.83	15,500.00	49.68	521.65	492.15	6,177.69	24,344.00
New Hampshire				993.50		2,014.31	3,007.81
New Jersey	20,700.00		2,147.74	2,502.75		718.02	26,068.51
New Mexico			1,500.00	1,000.00	1,000.00	1,500.00	5,000.00
New York	545,991.32		19,004.40				564,995.72
North Carolina (West Raleigh)		25,492.70	293.16	500.00	11,000.00	851.91	38,137.77
North Carolina (Greensboro)			290.84		512.32	1,321.56	2,154.72

North Dakota			350.00	2,350.00	1,230.00	850.00	4,780.00
Ohio	4,663.15	63,733.18	5,000.00	d12,828.00		1,472.07	87,696.40
Oklahoma (Stillwater)		45,000.00	1,420.44	1,000.00		100.00	47,520.44
Oklahoma (Langston)		18,661.85	300.00	200.00	400.00	200.00	19,761.85
Oregon		18,522.15	822.33	325.91	737.14	232.42	20,639.95
Pennsylvania		240,000.00	1,000.00				241,000.00
Rhode Island		2,900.00	550.00	200.00	70.00		3,720.00
South Carolina (Clemson College)		38,722.77	1,000.00	5,000.00	5,000.00		49,722.77
South Carolina (Orangeburg)				427.00	148.00		575.00
South Dakota		50,000.00	300.00	1,000.00	1,200.00		52,500.00
Tennessee		350.00	500.00	300.00	500.00	900.91	2,550.91
Texas (College Station)		31,000.00	1,000.00				32,000.00
Texas (Prairieview)		4,700.00	350.00			300.00	5,350.00
Utah		47,117.71	957.48	2,400.52		6,563.17	57,038.88
Vermont	10,000.00	25,000.00	2,000.00	12,000.00	500.00		49,500.00
Virginia (Blacksburg)		41,125.00		1,081.00	4,910.00	4,588.59	51,704.59
Virginia (Hampton)	128,685.00						128,685.00
Washington		14,000.00	590.90	3,519.37	4,854.95	1,164.36	24,129.58
West Virginia (Morgantown)			3,000.00	500.00	11,958.00		15,458.00
West Virginia (Institute)		16,000.00	200.00	300.00	498.00	214.00	17,212.00
Wisconsin		30,936.18	6,626.01			b39,245.01	76,807.20
Wyoming		4,000.00	6,000.00	4,000.00	2,000.00	300.00	16,300.00
Total	1,115,905.46	1,785,125.39	134,102.70	103,433.83	150,925.54	123,710.04	3,413,202.96

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[a] Including grounds.
[b] Including apparatus and machinery.
[c] Including apparatus.
[d] Including machinery.

Table 7.—*Disbursements from the United States Treasury to the States and Territories of the appropriations in aid of colleges of agriculture and the mechanic arts under the act of Congress approved August 30, 1890.*[a]

State or Territory.	Year ending June 30—													
	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.
Alabama	$15,000	$16,000	$17,000	$18,000	$19,000	$20,000	$21,000	$22,000	$23,000	$24,000	$25,000	$25,000	$25,000	$25,000
Arizona	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24.000	25,000	25,000	25,000	25,000
Arkansas	15,000	16,000	17,000	18,000	19.000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
California	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Colorado	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Connecticut	15,000	16,000	17,060	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Delaware	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Florida	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Georgia	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Idaho				18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Illinois	15,000	16,600	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Indiana	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000

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[a] From the annual statement of the Commissioner of Education to the Secretary of the Interior, 1902.

TABLE 7.—*Disbursements from the United States Treasury to the States and Territories of the appropriations in aid of colleges of agriculture and the mechanic arts under the act of Congress approved August 30, 1890*—Continued.

State or Territory.	Year ending June 30—													
	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.
Iowa	$15,000	$16,000	$17,000	$18,000	$19,000	$20,000	$21,000	$22,000	$23,000	$24,000	$25,000	$25,000	$25,000	$25,000
Kansas	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Kentucky	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Louisiana	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Maine	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Maryland	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Massachusetts	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Michigan	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Minnesota	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Mississippi	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Missouri	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Montana	....	....	....	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Nebraska	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Nevada	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
New Hampshire	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
New Jersey	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
New Mexico	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
New York	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
North Carolina	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
North Dakota	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Ohio	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Oklahoma	....	....	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Oregon	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Pennsylvania	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Rhode Island	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
South Carolina	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
South Dakota	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Tennessee	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Texas	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Utah	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Vermont	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Virginia	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Washington	....	....	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
West Virginia	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Wisconsin	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Wyoming	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	25,000	25,000	25,000
Total	660,000	704,000	782,000	864,000	912,000	960,000	1,008,000	1,056,000	1,104,000	1,152,000	1,200,000	1,200,000	1,200,000	1,200,000

STATISTICS OF THE AGRICULTURAL EXPERIMENT STATIONS.

TABLE 8.—*General statistics, 1902.*

Station.	Location.	Director.	Date of original organization.	Date of organization under Hatch Act.	Number on staff.	Number of teachers on staff.	Number of persons on staff who assist in farmers' institutes.	Publications during fiscal year 1901–2.		Number of addresses on mailing list.	Principal lines of work.
								No.	Pages.		
Alabama (College)	Auburn	C. C. Thach [a]	Feb. —, 1883	Feb. 24, 1888	13	8	6	7	467	9,182	Botany; soils; analyses of fertilizers and food materials; field and pot experiments; horticulture; plant breeding; diseases of plants; feeding experiments; diseases of animals; dairying.
Alabama (Canebrake)	Uniontown	J. M. Richeson	Jan. 1, 1886	Apr. 1, 1888	3	......	1	.....	....	300	Soil improvement; field experiments; horticulture; floriculture; diseases of plants; diseases of animals; dairying.
Alabama	Tuskegee	G. W. Carver	Feb. 15, 1897	....	11	7	9	10	80	2,000	Field experiments; horticulture; diseases of plants; animal industry; dairying.
Arizona	Tucson	R. H. Forbes	....	1889	8	5	3	7	228	5,100	Chemistry; botany; field experiments; improvement of ranges; horticulture, including date-palm culture; feeding experiments; irrigation.
Arkansas	Fayetteville	R. L. Bennett	....	1887	6	2	4	5	156	8,000	Chemistry of foods; field experiments; horticulture; plant breeding; diseases of plants; feeding experiments; diseases of animals.
California	Berkeley	E. W. Hilgard	1875	Mar. —, 1888	31	14	....	.....	....	8,100	Physics; chemistry and geographical distribution of soils; bacteriology; fertilizers; field crops; horticulture; botany; meteorology; technology of wine and olive oil, including zymology; beet-sugar chemistry; chemistry of foods and feeding stuffs; animal husbandry; entomology; dairying; drainage and irrigation; reclamation of alkali lands; plant introduction.

[a] Acting director.

TABLE 8.—*General statistics, 1902*—Continued.

Station.	Location.	Director.	Date of original organization.	Date of organization under Hatch Act.	Number on staff.	Number of teachers on staff.	Number of persons on staff who assist in farmers' institutes.	Publications during fiscal year 1901-2.		Number of addresses on mailing list.	Principal lines of work.
								No.	Pages.		
Colorado	Fort Collins	L. G. Carpenter	1879	Feb. —, 1888	15	10	7	26	249	7,300	Chemistry; field experiments; horticulture; plant breeding; entomology; irrigation.
Connecticut (State)	New Haven	E. H. Jenkins	Oct. 1, 1875	May 18, 1887	16	......	5	7	572	10,500	Chemistry; analysis and inspection of fertilizers, foods, and feeding stuffs; inspection of Babcock test apparatus and nurseries; diseases of plants; forestry; field experiments; entomology.
Connecticut (Storrs)	Storrs	L. A. Clinton[a]	....	...do...	14	11	3	2	215	7,000	Food and nutrition of man and animals; bacteriology of dairy products; field experiments; dairying.
Delaware	Newark	A. T. Neale	....	Feb. 21, 1888	6	6	6	7	347	7,278	Chemistry; bacteriology; field experiments; horticulture; diseases of plants; feeding experiments; diseases of animals; entomology; dairying.
Florida	Lake City	T. H. Taliaferro	....	1888	13	7	5	2	35	5,000	Chemistry; field experiments; horticulture; feeding experiments; veterinary science; entomology.
Georgia	Experiment	R. J. Redding	Feb. 18, 1888	July 1, 1889	7	1	....	4	282	9,000	Field experiments; horticulture; entomology; pig feeding; dairying.
Idaho	Moscow	H. T. French	....	Feb. 26, 1892	8	7	6	4	59	3,500	Chemistry; physics; botany; field experiments; horticulture; entomology; feeding experiments.
Illinois	Urbana	E. Davenport	....	Mar. 21, 1888	22	10	11	10	219	19,500	Chemistry; bacteriology; field experiments; horticulture; forestry; plant breeding; diseases of plants; diseases of animals; feeding experiments; entomology; dairying.
Indiana	Lafayette	H. A. Huston	1885	Jan. —, 1888	10	7	9	6	198	8,456	Chemistry; pot and field experiments; horticulture; feeding experiments; diseases of plants and animals.
Iowa	Ames	C. F. Curtiss	....	Feb. 17, 1888	21	14	10	5	165	20,000	Chemistry; botany; field experiments; horticulture; diseases of plants; feeding experiments; entomology; dairying.

Kansas	Manhattan	J. T. Willard		Feb. 8, 1888	17	13	15	8	276	23,350	Soils; horticulture; plant breeding; field experiments; feeding and digestion experiments; diseases of animals; entomology; dairying; extermination of prairie dogs and gophers.
Kentucky	Lexington	M. A. Scovell	Sept. —, 1885	Apr. —, 1888	16	......	4	8	305	8,300	Chemistry; soils; analysis of fertilizers, foods, and feeding stuffs; field experiments; horticulture; plant breeding; animal husbandry; diseases of plants; entomology; dairying.
Louisiana (Sugar)	New Orleans	W. C. Stubbs	Sept. —, 1885		26	4	10	6	279	15,000	Chemistry; bacteriology; soils and soil physics; field experiments; horticulture; sugar making; drainage; irrigation.
Louisiana (State)	Baton Rouge	do	Apr. —, 1886								Chemistry; geology; botany; bacteriology; soils; inspection of fertilizers and Paris green; field experiments; horticulture; animal husbandry; diseases of animals; entomology.
Louisiana (North)	Calhoun	do	May —, 1887								Chemistry; soils; fertilizers; field experiments; horticulture; feeding experiments; stock raising; dairying.
Maine	Orono	C. D. Woods	Mar. —, 1885	Oct. 1, 1887	12	7	3	11	240	7,000	Chemistry; botany; analysis and inspection of fertilizers, concentrated commercial feeding stuffs; and creamery glassware; horticulture; diseases of plants; seed tests; food and nutrition of man and animals; poultry raising; marine invertebrates; diseases of animals; entomology; dairying.
Maryland	College Park	H. J. Patterson	1888	Apr. —, 1888	15	8	6	9	219	12,500	Chemistry; soils; field experiments; horticulture; diseases of plants; feeding experiments; diseases of animals; entomology.
Massachusetts	Amherst	H. H. Goodell	[b]1882	Mar. 2, 1888	19	8	6	9	406	1,700	Chemistry; meteorology; analysis and inspection of fertilizers and concentrated commercial feeding stuffs; inspection of creamery glassware and nurseries; field experiments; horticulture; electro-germination; diseases of plants, digestion and feeding experiments; diseases of animals; entomology; dairying.
Michigan	Agricultural College.	C. D. Smith		Feb. 26, 1888	14	8	7	12	218	31,000	Chemistry; bacteriology; soils; field experiments, horticulture; diseases of plants, feeding experiments; diseases of animals; entomology; stable hygiene.

[a] Acting director.

[b] In 1882 the State organized a station here and maintained it until June 18, 1895, when it became a part of the Hatch Station at the same place.

TABLE 8.—*General statistics 1902*—Continued.

Station.	Location.	Director.	Date of original organization.	Date of organization under Hatch Act.	Number on staff.	Number of teachers on staff.	Number of persons on staff who assist in farmers' institutes.	Publications during fiscal year 1901-2.		Number of addresses on mailing list.	Principal lines of work.
								No.	Pages.		
Minnesota	St. Anthony Park, St. Paul.	W. M. Liggett	Mar. 7, 1885	1888	14	11		5	290	13,500	Chemistry; soils; field experiments; horticulture; forestry; diseases of plants; food and nutrition of man; plant and animal breeding; feeding experiments; diseases of animals; entomology; dairying.
Mississippi	Agricultural College.	W. L. Hutchinson.		Jan. 27, 1888	10	5	7	8	208	17,500	Soils; fertilizers; field experiments; horticulture; animal husbandry; diseases of animals; entomology; dairying.
Missouri (State)	Columbia	H. J. Waters		Jan. —, 1888	16	7	5	5	132	12,000	Chemistry; field experiments; horticulture; diseases of plants; feeding experiments; animal and plant breeding; diseases of animals; entomology. dairying; irrigation.
Missouri (Fruit)	Mountain Grove	J. T. Stinson	Feb. 1, 1900		4		3	1	20	3,000	Horticulture.
Montana	Bozeman	S. Fortier		July 1, 1893	9	6	7	5	178	1,812	Chemistry; meteorology; botany; field experiments; horticulture; feeding experiments; poultry experiments; entomology; irrigation.
Nebraska	Lincoln	E. A. Burnett	Dec. 16, 1884	June 13, 1887	17	9	8	5	159	16,000	Chemistry; botany; meteorology; soils; field experiments; horticulture; diseases of plants; forestry; feeding and breeding experiments; diseases of animals; entomology; irrigation.
Nevada	Reno	J. E. Stubbs			10	6	6	3	180	2,000	Chemistry; botany; soils; field experiments; horticulture; forestry; animal diseases; entomology; irrigation.
New Hampshire	Durham	F. W. Morse[a]	1886	Aug. 4, 1887	11	8	6	13	184	12,000	Chemistry; bacteriology; soil physics; draft and efficiency test of surface-working implements; field experiments; horticulture; diseases of plants; feeding experiments; entomology.

New Jersey (State)	New Brunswick	E. B. Voorhees	Mar. 10, 1880		12	2	4	5	497	10,000	Chemistry; biology; botany; analysis of fertilizers, foods, and commercial feeding stuffs; pot and field experiments; horticulture; diseases of plants; food and nutrition of man; diseases of animals; entomology; dairy husbandry; soil bacteriology; irrigation.
New Jersey (College)	do	do		Apr. 26, 1888	7	1	3	5	406		
New Mexico	Mesilla Park	Luther Foster		Dec. 14, 1889	11	7		5	166	3,200	Chemistry; botany; field experiments; horticulture; soils; feeding experiments; entomology; irrigation.
New York (State)	Geneva	W. H. Jordan	Mar. —, 1882		24		10	18	996	41,430	Chemistry; bacteriology; meteorology; fertilizers; analysis and control of fertilizers; inspection of creamery glassware; field experiments; horticulture; diseases of plants; feeding experiments; poultry experiments; entomology; dairying; irrigation.
New York (Cornell)	Ithaca	I. P. Roberts	1879	Apr. —, 1888	18	15	6	9	238	19,000	Chemistry of soils, feeding stuffs, and dairy products; soils; fertilizers; field experiments; horticulture; diseases of plants; feeding experiments; diseases of animals; poultry experiments; entomology; dairying.
North Carolina	Raleigh	B. W. Kilgore	Mar. 12, 1877	Mar. 7, 1887	12	6	6	2	140	25,000	Chemistry; soils; field experiments; horticulture; plant diseases; animal husbandry; diseases of animals; poultry experiments; dairying.
North Dakota	Agricultural College.	J. H. Worst		Mar. —, 1890	7	10	6	5	309	9,500	Field experiments; plant breeding; horticulture; diseases of plants; food analysis; feeding experiments; diseases of animals; dairying.
Ohio	Wooster	C. E. Thorne	Apr. 25, 1882	Apr. 2, 1888	15		4	8	195	43,000	Soils; field experiments; horticulture; plant breeding; diseases of plants; breeding and feeding experiments; diseases of animals; entomology.
Oklahoma	Stillwater	John Fields		Dec. 25, 1890	9	6	5	5	228	18,315	Chemistry; field experiments; horticulture; forestry; botany; diseases of plants; animal husbandry; diseases of animals; entomology.
Oregon	Corvallis	J. Withycombe		July —, 1888	11	7	4	5	208	4,300	Chemistry; bacteriology; soils; field crops; horticulture; diseases of plants; feeding experiments, entomology; dairying.
Pennsylvania	State College	H. P. Armsby		June 30, 1887	14	7	5	5	466	15,000	Chemistry; meteorology; analysis of fertilizers, foods, and feeding stuffs; horticulture; field experiments; feeding experiments; dairying.
Rhode Island	Kingston	H. J. Wheeler		July 30, 1888	11	3		8	203	6,604	Chemistry; meteorology; soils; analysis and inspection of fertilizers and feeding stuffs; field and pot experiments; horticulture; poultry experiments.

a Vice-director.

TABLE 8.—*General statistics, 1902*—Continued.

Station.	Location.	Director.	Date of original organization.	Date of organization under Hatch Act.	Number on staff.	Number of teachers on staff.	Number of persons on staff who assist in farmers' institutes.	Publications during fiscal year 1901-2.		Number of addresses on mailing list.	Principal lines of work.
								No.	Pages.		
South Carolina	Clemson College	P. H. Mell		Jan. —, 1888	17	12	11	9	212	9,000	Chemistry; analysis and control of fertilizers; field experiments; horticulture; plant breeding; diseases of plants; feeding experiments; veterinary science; entomology; dairying.
South Dakota	Brookings	J. W. Wilson		Mar. 13, 1887	12	6	....	4	132	9,000	Soils; field experiments; plant breeding; diseases of plants and animals; animal husbandry; dairying; irrigation.
Tennessee	Knoxville	A. M. Soule	June 8, 1882	Aug. 4, 1887	11	9	5	8	310	10,000	Chemistry; soils; fertilizers; field experiments; horticulture; seeds; weeds; diseases of plants; feeding experiments; entomology; dairying.
Texas	College Station	W. D. Gibbs			14	5	3	5	197	10,000	Chemistry; meteorology; soils; field experiments; horticulture; feeding experiments; diseases of animals; irrigation.
Utah	Logan	J. A. Widtsoe		1890	15	9	7	6	222	6,000	Chemistry of soils and feeding stuffs; alkali soil investigations; meteorology; field experiments; horticulture; diseases of plants; cattle and sheep breeding; feeding experiments; dairying; poultry experiments; irrigation; arid farming.
Vermont	Burlington	J. L. Hills	Nov. 24, 1886	Feb. 28, 1888	11	6	3	9	415	11,350	Chemistry; botany; analysis and control of fertilizers and feeding stuffs; inspection of creamery glassware; field experiments; horticulture; diseases of plants; feeding experiments; dairying.
Virginia	Blacksburg	J. M. McBryde	1888	1891	11	6	4	17	242	9,000	Field crops; horticulture; bacteriology; feeding experiments; veterinary science; entomology; cider and vinegar making; ferments.

Washington	Pullman	E. A. Bryan		1891	14	8	9	7	118	5,000	Chemistry; botany; bacteriology; soils; field experiments; horticulture; plant breeding; diseases of plants; feeding and breeding experiments; oyster culture; diseases of animals; entomology; dairying; irrigation.
West Virginia	Morgantown	J. H. Stewart		June 11, 1888	15	5	7	7	290	8,000	Chemistry; analysis and control of fertilizers; soils; field experiments; horticulture; inspection of orchards and nurseries; feeding experiments; poultry experiments; entomology.
Wisconsin	Madison	W. A. Henry	1883	1887	17	14	8	7	449	13,000	Chemistry; bacteriology; soils; field experiments; horticulture; feeding experiments; dairying; drainage and irrigation.
Wyoming	Laramie	B. C. Buffum	1887	Mar. 1, 1891	8	8		5	204	3,700	Geology; botany; meteorology; waters; soils; range improvement; fertilizers; field experiments; food analysis; feeding experiments; entomology; irrigation.
Total					710	364	288	373	13,409	596,277	

TABLE 9.—*Revenue and additions to equipment in 1902.*

Station.	Hatch fund.	State.	Individuals and communities.	Fees.	Farm products.	Miscellaneous.	Total.	Additions to equipment in 1902.						
								Buildings.	Library.	Apparatus.	Farm implements.	Live stock.	Miscellaneous.	Total.
Alabama (College)	$15,000.00			$5,201.66	$736.59		$20,938.25	$175.14	$506.74	$302.76	$145.60	$193.75	$247.00	$1,870.99
Alabama (Canebrake)		$2,500.00					2,500.00	2,500.00	250.00		100.00	200.00	100.00	3,150.00
Alabama (Tuskegee)		1,500.00					1,500.00		100.00	40.00	25.00	80.00	75.00	320.00
Arizona	15,000.00	940.36		5.00	879.10	$108.60	16,933.06	700.00	50.00	60.00	330.00	730.00	290.00	2,160.00
Arkansas	15,000.00				1,230.57		16,230.57	162.31	80.08	58.65	570.00	23.95		894.99
California	15,000.00	11,923.00			549.22		27,472.22	83.00	41.13	12.90				170.03
Colorado	15,000.00				1,036.26	[a]1,989.83	18,026.09	600.00	117.87	530.00	105.00			1,352.87
Connecticut (State)	7,500.00	15,500.00	$2,301.38	5,322.85	1,241.00	52.46	31,917.69		593.71	106.45			292.90	993.09
Connecticut (Storrs)	7,500.00	1,800.00			119.21		9,419.21	308.58		520.33	9.00	12.15		850.06
Delaware	15,000.00						15,000.00	267.01	518.38	366.93	58.89		1,491.62	2,702.77
Florida	15,000.00				1,271.71		16,271.71	300.00	137.93	17.75	176.00	397.93		1,029.61
Georgia	15,000.00	740.25			2,263.26	[b]2,498.49	20,502.00		25.00		100.00	50.00		175.00
Idaho	15,000.00	1,000.00			965.75		16,965.75		125.00	120.00	175.75			420.75
Illinois	15,000.00	54,000.00		600.00	216.92	[b]865.24	70,712.16	108.53	127.69	345.35	136.87	495.00	461.19	1,671.63
Indiana	15,000.00				[a]3,306.48		18,306.48	42.26	108.75	16.20	187.67	145.00		499.88
Iowa	15,000.00			6.00	1,304.61	27.51	19,338.12	43.97	10.00	562.26	490.83	99.00		1,206.06
Kansas	15,000.00				1,351.68	[b]800.96	17,152.64	3,000.60	76.85	3,772.57	336.50	37.00	7,260.96	11,484.48
Kentucky	15,000.00	[a]4,683.62		[a]26,393.58	[a]6,501.02	[a]331.51	52,909.73	1,296.96	919.45	245.21	399.51	2,101.00	609.90	5,572.03
Louisiana	15,000.00	17,000.00		8,000.00	1,866.05	[a]8,341.14	50,207.19	659.07	17.96	65.98	337.20	579.21	1,704.14	3,363.56
Maine	15,000.00			[c]1,213.25	3,078.66	[b]73.89	22,365.80		218.09	100.00	100.00			418.09
Maryland	15,000.00				4,808.89	[b]723.34	20,532.23	1,493.11	358.93	97.40	1,005.80	64.93		3,020.17
Massachusetts	15,000.00	11,200.00		3,405.00	2,274.66	2,319.66	31,199.32		284.40	703.21	538.16	664.02		2,189.79
Michigan	15,000.00	5,000.00		1,860.00	2,736.08	[a]1,976.14	26,572.22	1,914.19	202.22	823.51	243.30			3,213.22
Minnesota	15,000.00	[d]42,130.01			[d]13,579.11		70,709.12	28,000.00	1,000.00	552.70	847.10	3,585.25		33,985.35
Mississippi	15,000.00				1,112.32	[a]277.37	16,389.69	45.00	132.00		485.00	300.00	50.00	1,012.00
Missouri (State)	15,000.00			2,087.69	3,460.85	[a]3,842.89	24,391.43	75,000.00	150.00	150.00	75.00	1,400.00		76,775.00
Missouri (Fruit)		[e]26,525.00					26,525.00	2,000.00	225.00	825.00	120.00	180.00	300.00	3,950.00
Montana	15,000.00	825.09			4,183.61		20,008.70	417.45	50.00	186.36	185.05	500.00	269.30	1,608.16
Nebraska	15,000.00				1,613.18	[b]983.56	20,596.74	823.46	151.03	681.80	309.55	1,205.00	2,139.69	5,310.53
Nevada	15,000.00				598.49	[b]432.57	16,031.06	621.23	49.68	58.38	248.80		555.70	1,533.79
New Hampshire	15,000.00			592.50			15,592.50		253.86	286.73	129.11		351.65	1,021.35
New Jersey (State)		20,000.00					20,000.00		91.24	965.31			727.18	1,783.73
New Jersey (College)	15,000.00						15,000.00		620.13	201.22	101.00		88.67	1,017.02
New Mexico	15,000.00				1,115.42		16,115.42	1,064.57	156.56	4.59	1,270.68	377.25	504.04	3,377.69
New York (State)	1,500.00	74,847.55				[f]5,558.97	81,906.52		600.00	36.69		176.00		812.69
New York (Cornell)	13,500.00	[g]12,666.67			[a]583.21	[a]538.56	27,288.44	2,150.00	150.00	188.57	178.00			2,666.57
North Carolina	15,000.00	[g]5,000.00			199.73		20,199.73		12.97	49.00	211.98	1,580.45		1,851.40
North Dakota	15,000.00				1,959.85	966.25	17,926.10		19.00	417.89	478.67	350.00		1,265.56
Ohio	15,000.00	21,900.00		324.80	[a]9,632.59	[a]12,591.31	59,448.70	1,175.65	153.98	14.07	129.76		78.96	1,552.42
Oklahoma	15,000.00				2,500.00	[b]838.93	18,338.93	1,194.40	14.70	32.76	376.31		276.89	1,895.06
Oregon	15,000.00				[a]1,973.73		16,973.73	602.15	70.46	98.12	139.54	538.06		1,448.33

Pennsylvania	15,000.00			10,201.00	3,324.61	663.89	29,189.50		670.21	2,176.48	165.75	71.00	688.18	3,771.62
Rhode Island	15,000.00				1,052.01	[a]278.79	16,330.80	2,363.71	518.31	175.39	378.30			3,435.71
South Carolina	15,000.00				1,030.39		16,030.39	210.82	189.03	292.18	192.05	804.52		1,688.60
South Dakota	15,000.00	1,000.00			437.01	213.58	16,650.59	678.19		509.18	214.45		254.37	1,656.19
Tennessee	15,000.00				3,074.28	[h]734.92	18,809.20	473.19	267.96	141.78	254.45	500.00	25.00	1,662.38
Texas	15,000.00	15,000.00				[a]659.22	30,659.22	309.65	76.62	371.41	13.74	22.00	100.87	894.29
Utah	15,000.00				1,819.67	[a]712.01	17,531.68	12,000.00	67.82	262.25	276.70	400.00	54.43	13,061.20
Vermont	15,000.00	1,000.00		3,483.53	7,032.76		26,516.29	1,482.49	137.13	330.32	371.41	424.00		2,745.35
Virginia	15,000.00					20.81	15,020.81			209.18				209.18
Washington	15,000.00	6,089.57				[i]645.51	21,735.08	22,000.00	6.00	216.35	54.34	379.12	289.70	22,945.51
West Virginia	15,000.00			8,045.50	436.64	120.00	23,602.14	2,467.06	256.08	345.17	42.55	544.21		3,655.07
Wisconsin	15,000.00	[g]15,000.00		1,200.00			31,200.00	6,000.00	479.00	447.00	1,342.00	483.00		8,751.00
Wyoming	15,000.00				1,157.42		16,157.42	1,050.00	500.00	601.60	516.98	861.47	221.75	3,751.80
Total	720,000.00	369,771.12	2,301.38	80,942.36	105,641.60	50,187.91	1,328,847.37	176,113.78	11,941.98	19,727.94	14,982.56	20,554.27	19,509.09	262,829.62

[a] Including balance.
[b] Balance from previous year.
[c] For calendar year 1901.

[d] Including substations.
[e] For biennial period 1901 and 1902.
[f] Insurance.

[g] Estimated amount of State appropriation spent for experimental purposes.
[h] Dairy and live stock.
[i] Including fees and farm products.

TABLE 10.—*Expenditures from United States appropriation for year ended June 30, 1902.*[a]

Station.	Amount.	Itemized.																
		Salaries.	Labor.	Publications.	Postage and stationery.	Freight and express.	Heat, light, and water.	Chemical supplies.	Seeds, plants, and sundry supplies.	Fertilizers.	Feedingstuffs.	Library.	Tools, implements, and machinery.	Furniture and fixtures.	Scientific apparatus.	Live stock.	Traveling expenses.	Contingent expenses.	Building and repairs.
Alabama	$15,000.00	$8,610.00	$1,145.37	$1,146.90	......	$317.11	$329.61	$451.88	$830.17	$267.14	$322.41	$506.74	$392.14	$17.72	$302.76	$15.05	......	$15.00	......
Arizona	15,000.00	7,514.58	3,631.87	1,181.92	$257.60	331.24	124.36	235.97	167.63	257.62	169.83	43.38	332.41	289.38	63.99	25.25	$197.86	100.00	$72.11
Arkansas	15,000.00	8,305.25	2,097.50	920.13	335.78	405.28	14.24	235.52	621.49	1.40	670.76	80.08	570.00	......	58.65	23.95	384.66	110.00	162.31
California	15,000.00	6,989.92	4,371.29	418.34	310.87	104.51	135.58	762.31	618.61	......	319.20	48.83	55.91	89.00	42.90	......	641.73	5.00	83.00
Colorado	15,000.00	10,537.81	396.70	1,275.18	145.53	147.86	......	15.55	53.04	59.50	......	96.18	104.79	88.65	491.47	256.00	1,278.77	40.00	9.97
Connecticut (State)	7,500.00	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Connecticut (Storrs)	7,500.00	4,407.35	935.95	6.00	329.86	61.25	354.37	140.90	228.18	38.26	10.07	......	27.06	103.14	426.92	12.15	91.96	15.00	308.58
Delaware	15,000.00	9,210.00	978.17	1,154.59	193.00	101.18	351.80	94.82	496.52	......	51.98	518.38	58.80	337.03	366.93	......	700.70	116.06	267.01
Florida	15,000.00	6,061.05	3,714.68	1,069.55	344.62	182.60	322.60	37.78	438.30	304.08	1,254.39	126.68	170.75	......	8.07	397.93	251.92	15.00	300.00
Georgia	15,000.00	7,787.65	2,391.70	986.08	221.19	202.96	226.43	300.00	566.71	199.83	583.38	86.76	299.84	57.41	180.52	......	125.31	34.20	750.00
Idaho	15,000.00	8,166.62	3,051.95	411.53	57.85	138.75	967.34	299.07	199.53	1.15	66.22	44.22	175.75	87.49	120.00	......	351.05	125.05	736.43
Illinois	15,000.00	6,498.36	2,349.26	1,317.09	776.55	242.02	321.16	514.07	337.93	5.75	493.00	127.69	136.87	461.19	345.35	495.00	351.67	118.51	108.53
Indiana	15,000.00	8,601.19	2,396.19	689.20	77.57	155.74	504.31	12.97	647.74	7.25	817.29	108.75	304.85	32.65	16.20	171.08	117.76	28.05	308.21
Iowa	15,000.00	7,168.37	3,189.96	843.92	620.50	399.75	225.50	66.35	666.68	19.54	202.78	10.00	490.83	3.50	562.26	99.00	372.09	15.00	43.97
Kansas	15,000.00	7,870.03	3,142.62	635.89	221.79	198.87	87.85	112.48	305.66	6.00	791.19	78.53	110.85	207.27	218.47	550.26	258.59	33.70	166.95
Kentucky	15,000.00	11,440.00	1,187.62	122.80	179.45	95.41	26.82	341.74	144.23	......	......	919.45	71.95	106.25	199.21	......	14.48	85.81	64.75
Louisiana	15,000.00	8,087.37	3,221.53	609.40	170.76	247.23	239.35	275.00	422.50	158.09	717.06	17.96	275.89	......	53.97	473.89	......	......	......
Maine	15,000.00	7,882.52	1,788.15	245.00	243.65	229.75	953.09	330.20	409.49	157.17	1,000.33	218.09	116.63	113.26	103.64	248.50	259.62	15.00	685.91
Maryland	15,000.00	8,025.64	2,690.52	671.85	105.30	100.00	341.70	206.89	468.03	100.83	241.68	358.93	505.80	191.08	97.40	64.93	64.42	15.00	750.00
Massachusetts	15,000.00	7,366.88	2,224.12	1,205.64	359.37	60.57	765.27	......	530.60	444.25	210.83	140.53	538.16	28.95	59.24	410.93	150.57	131.15	372.94
Michigan	15,000.00	7,264.12	2,471.05	297.47	286.75	198.10	......	206.67	1,017.24	......	594.68	199.56	198.79	27.50	770.63	1,120.32	125.92	......	221.20
Minnesota	15,000.00	10,306.55	1,350.00	382.50	......	......	650.00	19.15	48.70	......	1,456.70	......	3.25	......	......	776.00	......	......	7.15
Mississippi	15,000.00	7,882.74	1,510.27	835.02	214.48	331.20	175.92	374.00	613.31	58.05	1,163.56	80.80	665.66	......	79.75	208.28	325.44	15.00	433.52
Missouri	15,000.00	6,403.19	2,158.02	248.29	101.93	599.68	188.02	130.88	366.84	1.50	2,515.13	145.25	97.42	32.30	150.16	1,378.60	299.64	15.00	168.15
Montana	15,000.00	9,018.25	2,215.06	1,232.88	182.68	438.17	281.72	135.56	470.12	32.50	105.51	223.81	185.05	269.30	186.36	......	......	23.00	......
Nebraska	15,000.00	8,259.83	1,498.65	1,010.79	764.87	171.18	......	283.20	764.06	......	1,004.66	151.03	66.00	245.93	257.17	105.00	50.05	......	367.58
Nevada	15,000.00	9,759.50	3,050.08	32.07	83.71	72.51	495.95	36.33	439.89	......	......	......	6.50	4.00	11.55	......	246.65	140.00	621.23
New Hampshire	15,000.00	9,010.39	1,825.13	1,329.35	95.21	92.00	583.37	102.49	378.59	186.90	7.00	253.86	153.93	351.65	286.73	......	293.79	20.60	29.01
New Jersey	15,000.00	9,580.00	953.51	1,506.93	268.68	82.61	279.15	56.37	160.90	156.41	154.62	620.13	104.00	228.94	204.22	......	383.66	171.20	88.67
New Mexico	15,000.00	6,821.05	2,691.65	245.56	504.41	771.36	97.54	2.80	711.20	111.00	259.32	156.56	1,317.53	505.04	4.59	377.25	388.14	35.00	......
New York (State)	1,500.00	......	......	1,187.75	33.10	......	......	19.60	......	......	......	2.00	......	75.00	......	......	37.66	141.89	......
New York (Cornell)	13,500.00	8,681.10	1,803.66	1,690.24	309.95	94.09	88.47	30.28	399.42	17.27	4.00	78.87	19.50	1.50	117.23	......	64.43	30.00	39.99
North Carolina	15,000.00	8,203.77	1,585.45	80.82	117.60	250.30	9.03	62.16	190.42	90.42	568.27	12.97	270.08	20.50	49.00	2,890.87	58.55	210.00	329.79
North Dakota	15,000.00	7,211.27	3,328.01	914.40	65.00	......	577.38	97.92	592.08	......	789.83	19.00	490.22	......	417.89	350.00	124.00	23.00	......
Ohio	15,000.00	12,102.63	585.92	......	179.12	15.62	312.06	......	646.06	175.45	379.83	52.55	388.47	79.22	......	......	......	15.00	68.07
Oklahoma	15,000.00	5,827.00	2,957.65	1,442.19	669.21	213.14	414.64	218.84	197.03	102.80	581.85	14.70	376.31	276.89	32.76	555.67	351.32	15.00	750.00
Oregon	15,000.00	10,463.50	2,114.52	469.85	71.23	131.75	......	247.86	133.59	15.13	423.00	70.46	139.54	......	98.12	......	......	19.30	602.15

Pennsylvania	15,000.00	10,978.76	6.50	24.20	225.82	....	149.01	875.46	64.84	176.03	951.50	327.25	33.64	4.25	218.57	398.14	242.25	25.00	298.78
Rhode Island	15,000.00	6,947.87	3,108.13	2.50	294.28	141.97	988.09	13.04	462.20	183.73	619.06	518.31	378.30	212.35	175.39	....	177.36	29.40	748.02
South Carolina	15,000.00	7,550.58	2,330.41	1,146.63	189.94	304.51	38.89	374.81	385.00	265.62	375.88	189.03	192.05	24.90	292.18	804.52	302.98	21.25	210.82
South Dakota	15,000.00	8,966.64	1,312.49	1,148.46	277.21	276.28	1.35	269.18	450.89	....	218.53	....	339.45	251.37	386.00	87.18	317.79	15.00	679.18
Tennessee	15,000.00	7,646.67	3,908.27	897.19	293.48	39.05	287.10	101.80	216.28	80.60	378.08	267.96	254.45	....	141.78	....	148.83	158.15	150.31
Texas	15,000.00	8,908.55	1,544.37	1,341.66	572.19	237.12	30.50	426.96	340.53	36.47	158.45	76.62	34.01	100.87	371.41	22.00	364.03	51.75	382.51
Utah	15,000.00	8,451.78	3,487.32	481.71	280.48	62.19	206.20	241.55	212.87	....	341.08	67.82	276.70	54.43	60.70	269.00	59.95	31.25	414.97
Vermont	15,000.00	6,616.35	2,806.68	1,124.86	397.56	158.58	481.31	202.92	131.91	36.60	1,252.71	137.13	34.68	132.41	330.32	27.00	312.53	66.45	750.00
Virginia	15,000.00	9,048.64	2,101.99	1,654.62	56.88	118.09	239.33	143.29	638.87	52.40	405.56	....	....	....	209.18	....	81.00	15.00	235.15
Washington	15,000.00	8,426.37	2,738.97	277.15	102.31	141.76	883.50	26.45	588.05	....	144.02	6.00	54.34	85.75	216.35	162.75	421.40	10.00	714.83
West Virginia	15,000.00	11,306.38	225.90	7.80	189.33	432.35	556.55	551.35	377.84	81.00	161.76	250.88	1.50	....	345.17	39.00	276.64	15.00	181.05
Wisconsin	15,000.00	8,908.33	2,368.16	....	115.05	85.73	35.00	654.97	1,118.15	9.83	243.70	452.05	125.00	....	166.73	360.00	312.75	2.00	42.55
Wyoming	15,000.00	4,350.17	3,731.94	1,109.86	573.25	466.90	624.41	221.75	276.56	7.50	332.16	34.85	516.98	388.95	212.65	861.47	648.81	27.00	614.79

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[a] The expenditures under the different heads are affected by the total revenue of the station, as shown in Table 9.

TABLE 11.—*Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the act of Congress approved March 2, 1887.*[a]

State or Territory.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.
Alabama	$11,250.00	$18,750.00	$14,999.34	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00
Arizona	....	....	10,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	14,816.71	14,987.09	14,999.35	15,000.00	15,000.00	15,000.00	15,000.00
Arkansas	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
California	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Colorado	11,250.00	18,713.24	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Connecticut	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Dakota (Territory)	11,250.00	18,750.00	15,000.00	11,250.00	....	....	....	....	....	....	....	....	....	....	....
Delaware	11,250.00	18,188.84	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Florida	11,250.00	18,750.00	14,998.05	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	14,970.36	14,998.07	14,999.63	15,000.00	15,000.00
Georgia	11,250.00	18,733.55	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Idaho	....	....	....	....	....	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Illinois	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Indiana	11,250.00	18,662.91	14,988.28	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Iowa	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Kansas	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Kentucky	11,250.00	18,746.57	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Louisiana	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Maine	11,250.00	18,750.00	14,999.75	14,999.87	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Maryland	11,250.00	18,725.28	14,998.65	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	14,993.47	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Massachusetts	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Michigan	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Minnesota	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Mississippi	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Missouri	11,250.00	13,391.66	15,455.58	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00

[a] This table was prepared in the Treasury for the use of this Department by the courtesy of the honorable Secretary of the Treasury.

TABLE 11.—*Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the act of Congress approved March 2, 1887*—Continued.

State or Territory.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.
Montana	....	....	....	....	....	....	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00
Nebraska	$11,250.00	$18,750.00	$15,000.00	$14,999.87	$15,000.00	$14,951.08	14,981.21	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Nevada	11,250.00	18,750.00	14,951.39	15,000.00	14,999.44	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	14,988.49	15,000.00	15,000.00	15,000.00
New Hampshire	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
New Jersey	11,250.00	18,711.97	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
New Mexico	....	....	10,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	14,998.90	15,000.00
New York	11,250.00	18,708.09	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	14,987.18	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
North Carolina	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
North Dakota	....	....	....	17,500.00	15,000.00	15,000.00	14,830.62	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Ohio	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Oklahoma	....	....	....	....	15,000.00	15,000.00	15,000.00	14,701.00	15,000.00	14,969.30	14,601.43	15,000.00	14,999.07	15,000.00	15,000.00
Oregon	11,250.00	11,250.00	9,132.52	15,000.00	13,791.71	16,207.59	15,000.00	15,000.00	15,000.00	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00
Pennsylvania	11,250.00	18,717.95	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Rhode Island	....	15,000.00	30,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
South Carolina	11,250.00	18,750.00	15,000.00	15,000.00	14,542.15	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
South Dakota	....	....	....	3,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	14,500.00
Tennessee	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Texas	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Utah	....	....	10,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Vermont	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.10
Virginia	11,250.00	18,742.57	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Washington	....	....	....	....	15,000.00	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
West Virginia	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	14,969.72
Wisconsin	11,250.00	18,750.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Wyoming	....	....	....	15,000.00	45,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Total	427,500.00	713,792.63	621,523.56	662,499.74	718,333.30	702,408.67	723,561.83	719,701.00	719,803.89	716,199.86	723,321.14	719,986.56	719,998.70	719,998.90	719,469.72

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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 129.

A. C. TRUE, Director.

DIETARY STUDIES

IN

BOSTON AND SPRINGFIELD, MASS., PHILADELPHIA, PA., AND CHICAGO, ILL.

BY

LYDIA SOUTHARD, ELLEN H. RICHARDS, SUSANNAH USHER,
BERTHA M. TERRILL, AND AMELIA SHAPLEIGH.

EDITED BY

R. D. MILNER.

1862 1889

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON THE FOOD AND NUTRITION OF MAN.

Note.—For those publications to which a price is affixed application should be made to the Superintendent of Documents, Union Bulding, Washington, D. C., the officer designated by law to sell Government publications. Publications marked with an asterisk (*) are not available for distribution.

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[Continued on third page of cover.]

U. S. DEPARTMENT OF AGRICULTURE.

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A. C. TRUE, Director.

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1862 1889

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

OFFICE OF EXPERIMENT STATIONS.

A. C. True, Ph. D., *Director.*
E. W. Allen, Ph. D., *Assistant Director and Editor of Experiment Station Record.*
C. F. Langworthy, Ph. D., *Editor and Expert on Foods and Animal Production.*

NUTRITION INVESTIGATIONS.

W. O. Atwater, Ph. D., *Chief of Nutrition Investigations, Middletown, Conn.*
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., April 28, 1903.

Sir: I have the honor to transmit herewith a report of a number of dietary studies which were offered to this Office for publication. These include investigations at the Boston School of Housekeeping by Miss Lydia Southard; a study at the same institution by Miss Susannah Usher and Miss Bertha M. Terrill; at the Bible Normal College, at that time located at Springfield, Mass., but now at Hartford, Conn., and designated School of Religious Pedagogy, by Miss Bertha M. Terrill; and of families of different nationalities living in the thickly congested districts of Philadelphia and Chicago, by Mrs. Ellen H. Richards and Miss Amelia Shapleigh. Much credit is due Miss Henrietta I. Goodrich, director of the Boston School of Housekeeping, for planning the series of studies carried on in that institution in 1901–2, and to Miss Annette Philbrick, fellow at the Boston School of Housekeeping, 1901–2, who rendered valuable assistance in carrying out the details of these studies. The preparation and editing of the material has been very largely the work of Mr. R. D. Milner, of the Office of Experiment Stations.

The studies at the Boston School of Housekeeping and the Bible Normal College are of special importance, since in all but one the cost of the food was decided upon beforehand, and an attempt was made to supply with the sum allowed a satisfactory and nutritious diet corresponding to the commonly accepted dietary standards. The studies, which were in the main successful as regards the object sought, are interesting and valuable attempts to apply in a practical way the accumulated results of nutrition investigations. All the data included are of value in themselves and useful for purposes of comparison and in other ways.

The report is submitted with the recommendation that it be published as Bulletin No. 129 of this Office.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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DIETARY STUDIES IN AMERICAN CITIES.

DIETARY STUDIES AT THE BOSTON SCHOOL OF HOUSEKEEPING, 1901–2.

By Lydia Southard, B. A.

INTRODUCTION.

The demand for accurate information upon the subject of nutrition has been partly met in the past by making dietary studies in widely separated places, and with persons in widely different circumstances. There is so much difficulty, however, in comparing dietaries observed under such varying conditions as those due to the personality of both the individuals in charge and those fed, their previous food habits, their local market limitations, etc., that the drawing of valuable conclusions is often prevented. It was therefore deemed worth while at the Boston School of Housekeeping, which is now incorporated with Simmons College, to make some comparisons of the effects of different dietaries upon the same family. The details and results of four studies in which the group of persons remained the same, but the cost of the diet was varied, and the quantity and quality of food materials varied accordingly, are here reported. The work was planned by the director of the school, Miss Henrietta I. Goodrich, in such a way that the diet could be modified in kind and cost. The usual methods were followed in this investigation and many of the details were attended to by Miss Annette Philbrick, fellow of the School of Housekeeping 1901–2.

Of the four dietary studies reported the first was made under the usual living conditions to find out the cost of the regular diet, and to learn how nearly it conformed to the commonly accepted dietary standard. In the second study it was designed to have the diet medium in cost—that is, between 20 and 30 cents per person per day, the diet finally selected costing on an average 25 cents. In the third study the attempt was made to furnish a reasonably attractive diet at a low cost, namely, less than 20 cents per person per day. The diet decided upon actually cost 17 cents. In the fourth study it was proposed to supply a diet of high cost, namely, one ranging from 50 to 60 cents per person per day. The diet actually supplied cost on an average 53 cents.

In all cases these values represent only the actual cost of the food, no account being taken of the cost of preparation and service.

The observations were confined to the teachers and pupils in residence at the School of Housekeeping, comprising fifteen women. The employees (house workers) in the school had a separate table, and for that reason were not included in these experiments. One of the difficulties experienced was the impossibility of conducting the work without the knowledge of those upon whom the experiments were made. At least two other conditions were unfavorable to the best results, namely, the shortness of time during which it was possible to continue each experiment, and the indifference of some of the family as to the success or failure of the undertaking. Those eating at the school table were of two distinct classes as regards their mental attitude toward the investigation: the teachers and professional students were thoroughly interested in the scientific side of the dietary work, but the remaining and larger portion of the group felt only the interest of average boarders. On the other hand, the facilities for gaining exact information were unusually good; and it is thought that a comparison and discussion of the varying results obtained in the same household may add something of value to what has already been done in the study of nutrition.

EQUIPMENT AND METHOD.

The primary necessity in the way of equipment for dietary studies is scales which are accurate, those employed in these studies being platform scales, with a weighing capacity of from one-quarter of an ounce to 300 pounds. For convenience in carrying out the details of the studies several utensils of various sizes were used for holding the supplies of different food materials that were to be used during the experiments, so that they could be easily weighed and kept separate from the general supplies for the rest of the household. Wooden buckets, with handles and close-fitting covers, were obtained at a kitchen-furnishing establishment. Not more than ten of these were required. They varied in capacity from 25 to 50 pounds, and in cost from 25 to 50 cents each. The buckets were used for sugar, flour, etc. Baskets and boxes given away by grocers in delivering their goods were collected for holding such commodities as fresh fruit, vegetables, and eggs. Glass and porcelain jars, with covers, were set aside for condiments, starches, and the like. Not more than five of each were usually needed in the same experiment. The glass jars held 1 quart each, and were of the sort ordinarily used for preserving fruit. The porcelain jars were smaller, and were of the sort in which marmalades and certain cheeses are sold. Standard tin measuring cups, holding exactly one-fourth of a liquid quart, were obtained for 10 cents each. Not more than six were really needed, two for the experimenters and four for use in the cooking. One wooden half-peck measure, costing 25 cents, was purchased at an agricultural-supply store. Three tin funnels of different sizes, and a number of plain and durable plates and bowls, all of which might be found in the average kitchen, completed the more substantial part of the outfit.

Prepared labels of two contrasting colors were found to be most useful as a means of distinguishing between receptacles for carefully weighed materials to be consumed in the experiments, and those containing unweighed articles to be used at other times. Firmly bound note books, for the preservation of all data, were also a great convenience.

Before the special dietary studies were undertaken a regular study was carried on with the family in their ordinary school life during two consecutive weeks taken at random. The menus followed in this study were those planned by the head of the house. Although the selection of food materials had been made according to a general knowledge of their nutritive values, no attempt was made in this case to regulate the cost nor to provide a diet that would furnish definite quantities of nutrients and energy.

Save for the fact that in the regular dietary study the cost and nutritive value of the diet were not predetermined, and that no attention was paid to table and kitchen wastes, the methods of procedure were the same as were followed in the special studies. The making of this study therefore served a double purpose; it gave practice, and afforded information which assisted greatly in deciding how to meet the requirements of the special studies that were to follow.

In making the studies in which the cost and nutritive value were regulated, it was necessary to select a favorable time, to study the markets in advance, and to pay attention to other points, as explained in the following paragraphs:

Date.—The first thing to be determined in each case was the most favorable time for beginning the study and the length of time it was to continue. Obviously, in a locality where the cost of eggs, fresh fruit, etc., changes so often, it is necessary, if the expenditure is limited, to consider the seasons carefully before making out in advance a menu for a diet of definite cost.

Price lists of local food supply.—The dates having been fixed, those in charge of the work consulted their dealers, to learn in advance as nearly as possible the cost of foods at the times decided upon. The result of these inquiries was a full price list upon which the bill of fare could safely be based.

Planning the menu.—The planning of the menu was the next step. Guided by the cost of food as already ascertained, the workers arranged a programme for meals which conformed as well as possible, under the circumstances, to the following requirements: (1) proper proportions of nutrients and energy; (2) adequate quantities of food materials; (3) wholesome combinations; (4) acceptable dishes; and (5) economy. That is, the persons in charge endeavored not only to approach the scientific standard of a properly balanced dietary, but also to recognize all normal healthy tastes of the school family, so far as possible, while at the same time keeping within the financial bounds of the experiment.

With the proposed menu as a foundation, the cook and the cook books were consulted to learn what amounts of the different raw materials would be required. This done, a set of tables was made out, giving the cost and nutritive value of such a bill of fare. These tables, together with the menus for the experiment, were called, for convenience, the "tentative dietary." The reason for working out this "tentative" statement in such detail was to discover, before it was too late, whether or not the menu decided upon could be given to the family at the price allowed for the experiment; and whether, if the estimated quantities were fully or nearly consumed, the person eating the food would receive an adequate and properly balanced diet. The "tentative dietary" was criticised and altered before each experiment, as the financial or nutritive needs of the case demanded. The revised and improved "tentative" was then called the "estimated dietary." Care was always taken to have the latter furnish approximately 90 grams of protein and 2,450 calories of energy per woman per day in accordance with the commonly accepted American dietary standard for a woman at light muscular work.

Marketing.—Data for the marketing lists were then gathered from the column of "amounts" in the "estimated" tables, and the marketing for the experiment was done. In most cases, those having charge of the dietaries confined themselves to shops regularly patronized by the school. In the experiment with the 17-cent diet, however, some shops carrying cheaper goods were visited in order to secure the needed foods at lower prices.

Weighing.—It was found desirable in weighing uncooked food to learn the weight of each receptacle when empty and to label it accordingly. Those having covers were always weighed without them to avoid inaccuracies in case the covers should ever be exchanged.

The day before beginning the experiment it was the custom to weigh all the staples on hand which were required for the entire period. The more perishable food stuffs, which were obtained only as needed, were weighed from day to day as soon as they were received from the shops.

Account of these weights was kept in a notebook prepared beforehand, which contained a classified list of edibles to be used in the work. Sufficient space was left under each heading for the entries in all experiments.

After each meal the "left overs" of any sort were weighed and the weights recorded. The quantities were usually too small to appear again upon the school family table. When this was the case the food was later used by the employees. This made for the experimenters a complication peculiar to establishments where two distinct tables are supplied. It was necessary to calculate from the recipes of all "made dishes" the exact amount of each ingredient in the material not consumed, and deduct it from the quantities originally set aside for the dietary.

Waste.—During some of the experiments, the amount of waste and refuse was weighed and recorded. In these cases the amounts of kitchen waste, consisting of such articles as potato parings, coffee grounds and the like, were recorded after each meal. At the same time account was kept of the kinds and amounts of uneaten fragments left upon the plates at table.

When the study was over an inventory was taken of raw materials which had not been used. The amounts on hand, like the ingredients of the "left overs," were deducted from the weights recorded at the beginning or purchased during the study. From this result the amount of waste might be subtracted, in which case the figures obtained would represent food actually eaten.

Computation of results.—On the basis of the real, as distinguished from the "estimated" weights, new tables were made out, showing the cost and nutritive value of what had been consumed. These tables constitute what we called the "actual" or "final" dietary, and in a condensed form they are given beyond.

None of the food materials from these studies was analyzed. The composition of all materials used was assumed to be the same as that of the average values for similar materials recorded in a previous publication of the Office of Experiment Stations,[a] except in a few cases in which analyses were taken from an unpublished compilation. The values used in computing the results of the studies are given in Table 29 of the Appendix. The reference numbers in the first column of this table correspond with those in parentheses following the weight and cost of the food materials in the table for each study, and thus indicate the composition assumed for each material. The fuel value of the materials was computed by use of the following factors: For protein and carbohydrates 4 calories per gram, and for fat 8.9 calories.

DIETARY UNDER USUAL CONDITIONS (No. 1a).

The study began November 7, 1901, and lasted fourteen days. The members of the family who were eating the regular food, and could therefore be considered in all experiments, were three teachers and twelve students, a group of fifteen women. All of these were in good health. The average weight of these persons was approximately 125 pounds each. There were a few absences during the period of two weeks, and an occasional guest came to the table; but an accurate account was kept of the whole number of meals served, which was 632, equivalent to 1 woman for 211 days.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 28, revised.

The bill of fare for the fourteen days follows:

Daily menu.

THURSDAY, NOVEMBER 7.

Breakfast.—Fresh fruit, wheat breakfast food,[a] bacon, creamed potatoes, morningside rolls.

Luncheon.—Baked beans and tomato soup, creamed dried beef, rice croquettes, dates and peanuts.

Dinner.—Rump steak, spaghetti and cheese, escalloped tomato, lettuce and radish salad, cheese wafers, Rebecca pudding with boiled custard.

FRIDAY, NOVEMBER 8.

Breakfast.—Fresh fruit, wheat breakfast food, creamed eggs, fried potatoes, graham muffins.

Luncheon.—Escalloped oysters, cabbage salad, samp, baked apples, cookies, Russian tea.

Dinner.—Clear beef-stock soup, baked halibut with tomato sauce, mashed potatoes, baked Hubbard squash, chocolate ice cream.

SATURDAY, NOVEMBER 9.

Breakfast.—Fresh fruit, wheat breakfast food, codfish hash, wheat rolls.

Luncheon.—Meat pie (rump), spaghetti with cheese, lettuce salad, gingerbread, cream cheese, Russian tea.

Dinner.—Clear stock soup, braised beef, mashed potatoes, fried parsnips, cranberry jelly, Norwegian prune pudding, cream sauce.

SUNDAY, NOVEMBER 10.

Breakfast.—Fresh fruit, shredded-wheat biscuit, Boston brown bread, baked beans.

Dinner.—Braised fowl, sweet potatoes, turnips, cranberry jelly, lettuce and radish salad, cheese wafers, brown bread, ice cream.

Supper.—Vegetable salad, bread and butter, cocoa, preserved peaches, Newport cakes.

MONDAY, NOVEMBER 11.

Breakfast.—Fresh fruit, wheat breakfast food, corn bread, corned-beef hash.

Luncheon.—Clear chicken soup, beef stew, baked potatoes, celery, rice pudding with cream.

Dinner.—Boiled leg of mutton with egg sauce, mashed potatoes, beans, lettuce salad, cheese wafers, hickory nuts, raisins, coffee.

TUESDAY, NOVEMBER 12.

Breakfast.—Fresh fruit, rolled-oat breakfast food, dropped eggs on toast, graham muffins.

Luncheon.—Cold roast beef, crab-apple jelly, samp, lettuce salad, baked indian pudding with cream, Russian tea.

Dinner.—Clear stock soup, baked ham, mashed potatoes, spinach, lemon sherbet.

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[a] Different kinds were used during the study to give variety.

WEDNESDAY, NOVEMBER 13.

Breakfast.—Fresh fruit, wheat breakfast food, bacon, baked potatoes, hot rolls.

Luncheon.—Escalloped mutton, Saratoga potatoes, celery, chocolate, bread pudding with hard sauce.

Dinner.—Roast rump, browned potatoes, succotash, grape jelly, lettuce salad, cheese wafers, coffee jelly with cream, sugar cookies.

THURSDAY, NOVEMBER 14.

Breakfast.—Fresh fruit, shredded-wheat biscuit, sausage, brewis, graham rolls.

Luncheon.—Baked beans and tomato soup, cold sliced ham, Spanish pickle, spaghetti with cheese, baked apples, Russian tea.

Dinner.—Cream of Lima bean soup, toasted Boston crackers, rump steak, mashed potatoes, peas, barberry jelly, tapioca cream.

FRIDAY, NOVEMBER 15.

Breakfast.—Fresh fruit, wheat breakfast food, codfish balls, hot rolls.

Luncheon.—Finnan haddie, baked potatoes, celery, apple pie, cheese, Russian tea.

Dinner.—Cream of clam chowder, escalloped fish, baked sweet potatoes, parsnip cakes, celery, steamed apple pudding with foam sauce.

SATURDAY, NOVEMBER 16.

Breakfast.—Fresh fruit, wheat breakfast food, creamed dried beef, fried potatoes, corn bread.

Luncheon.—Cold sliced rump beef, samp, lettuce salad, hot gingerbread, cream cheese, Russian tea.

Dinner.—Clear stock soup, corned beef, boiled potatoes, boiled cabbage, creamed carrots, lemon jelly.

SUNDAY, NOVEMBER 17.

Breakfast.—Shredded-wheat biscuit, Boston baked beans, brown bread, doughnuts.

Dinner.—Split-pea soup, braised fowl, mashed potatoes, baked squash, cranberry jelly, frozen fig pudding, coffee.

Supper.—Creamed oysters, bread and butter, cocoa, Newport cakes.

MONDAY, NOVEMBER 18.

Breakfast.—Fresh fruit, wheat breakfast food, corned-beef hash, popovers.

Luncheon.—Escalloped fowl, Saratoga potatoes, cabbage and celery salad, cup cakes, Russian tea.

Dinner.—Braised beef, browned potatoes, salsify, Spanish pickle, vegetable salad, cheese wafers, Irish moss blanc mange with cream, orange marmalade.

TUESDAY, NOVEMBER 19.

Breakfast.—Fresh fruit, wheat breakfast food, scrambled eggs with chopped ham, Boston brown bread.

Luncheon.—Meat pie (rump beef), samp, pickled beets, junket pudding, sugar cookies, Russian tea.

Dinner.—Clear stock soup, boiled leg of mutton with caper sauce, escalloped onions, browned sweet potatoes, tapioca pudding with cream.

WEDNESDAY, NOVEMBER 20.

Breakfast.—Fresh fruit, rolled-oat breakfast food, bacon, baked potatoes, wheat muffins.

Luncheon.—Casseroles of mutton and rice, tomato sauce, Saratoga potatoes, celery, pumpkin pie, cheese.

Dinner.—Rump steak with horseradish sauce, mashed potatoes, escalloped tomatoes, watercress salad, cheese wafers, coffee jelly with whipped cream.

The choice of coffee, cocoa, or milk was given each morning at breakfast. Heavy cream was always furnished with coffee in the morning, and thin cream was supplied for the cereal. When not otherwise specified in the menus, thin cream was served with dessert. French dressing was served in all cases with the salads mentioned above. The fresh fruit served at breakfast was always either apples, pears, grapes, or bananas. Cold bread, either wheat or graham, while not mentioned in the menus, was furnished three times a day to those who desired it. Butter was served at breakfast and luncheon, but not at dinner.

According to the usual custom of the house, an 11 o'clock luncheon of crackers and milk was offered 5 days in the week. These luncheons do not appear in the menu, but the amounts of food eaten have been taken account of in the tables with the other materials.

The cost of the diet in this study was based upon wholesale rates, at which most of the food stuffs used at the school were bought. In addition to the food materials purchased, the beverages and condiments, as coffee, pepper, salt, etc., used during the whole study cost $3.55, or 1.7 cents per woman per day.

The details of the study follow.

TABLE 1.—*Weights and cost of food and nutrients in dietary study No. 1a.*

Food consumed during the entire study (14 days).		Cost, nutrients, and fuel value of food per woman per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Rump roast, 33.53 pounds, $4.52 (13); shin, 7.75 pounds, 39 cents (18); steak, rump, 14.09 pounds, $1.90 (31); corned beef, 6.88 pounds, 83 cents (2); dried beef, 3.92 pounds, 90 cents (4); soup stock, 2.08 pounds (22); suet, 0.38 pound, 2 cents (35). Mutton, leg, 1.72 pounds, 23 cents (48)	8.79	4.2	21	27	....	324
Pork: Fresh, 2.17 pounds, 28 cents (59); salt pork, 2.46 pounds, 15 cents (64); bacon, 0.97 pound, 14 cents (56); ham, 9.33 pounds, $1.21 (60); sausage, 3.13 pounds, 38 cents (66); lard, 0.18 pound, 2 cents (62)	2.18	1.0	5	17	....	171
Poultry, fowl, 22.34 pounds, $3.13 (75)	3.13	1.5	7	6	....	81
Fish: Cod, salt, 1.88 pounds, 24 cents (80); haddock, 2.25 pounds, 14 cents (84); halibut, 1.67 pounds, 36 cents (85); clams, 3.73 pounds, 36 cents (78); oysters, 8.38 pounds, $1.42 (93); Finnan haddie, 5.56 pounds, 45 cents (83)	2.97	1.4	6	1	1	37
Eggs, 16.47 pounds, $1.54 (105)	1.54	.7	5	3	....	47
Cream: Thin, 13.46 pounds, $1.56 (113); heavy, 9.59 pounds, $2.76 (113)	4.32	2.0	1	9	2	92
Milk, 221.63 pounds, $5.99 (114)	5.99	2.8	16	19	24	329
Butter, 31.72 pounds, $8.24 (106)	8.24	3.9	1	58	....	520
Cheese: Pale, 1.56 pounds, 23 cents (108); full cream, 0.79 pound, 46 cents (111)	.69	.3	1	2	....	22
Total animal food	37.85	17.8	63	142	27	1,623

TABLE 1.—*Weights and cost of food and nutrients in dietary study No. 1a*—Continued.

Food consumed during the entire study (14 days).		Cost, nutrients, and fuel value of food per woman per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
VEGETABLE FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Cereals: Corn meal, yellow, 2.97 pounds, 8 cents (119); oat breakfast food, 1.52 pounds, 9 cents (129); samp, 1.84 pounds, 6 cents (134); wheat breakfast food, 3.65 pounds, 29 cents (137); shredded wheat, 0.45 pound, 5 cents (143); wheat breakfast food, 0.97 pound, 5 cents (136); wheat breakfast food, 0.60 pound, 7 cents (142); flour, bread, 45.41 pounds, $1 (122); flour, pastry, 2.66 pounds, 7 cents (125); flour, entire wheat, 3.39 pounds, 14 cents (123); bread, graham, 0.91 pound, 3 cents (145); bread, wheat, 8.55 pounds, 25 cents (147); bread, Boston brown, 0.72 pound, 1 cent (144); rolls, 0.28 pound, 1 cent (160); crackers, Boston, 2.70 pounds, 22 cents (154); wafers, salted, 2.48 pounds, 53 cents (161); cookies, sugar, 0.31 pound, 3 cents (152); spaghetti, 1.34 pounds, 13 cents (135)	3.11	1.5	19	3	128	615
Sugars, starches, and oils: Sugar, brown, 0.20 pound, 1 cent (162); sugar, cut loaf, 9.36 pounds, 62 cents (163); sugar, granulated, 24.86 pounds, $1.36 (163); sugar, powdered, 1.02 pounds, 6 cents (163); molasses, dark, 9.73 pounds, 20 cents (165); oil, cotton-seed, 0.50 pound, 5 cents (170); oil, olive, 1.73 pounds, 36 cents (171); cornstarch, 0.86 pound, 7 cents (172); tapioca, 0.54 pound, 2 cents (173); Irish moss, 0.31 pound (169); chocolate, 0.67 pound 19 cents (167); cocoa, 0.73 pound, 33 cents (168)	3.27	1.5	1	6	95	137
Vegetables: Beans, Lima, 0.22 pound, 2 cents (176); beans, pea, 1.65 pounds, 16 cents (177); beans, string (canned), 4.83 pounds, 77 cents (179); cabbage, 3.08 pounds, 10 cents (181); carrots, 3.81 pounds, 16 cents (182); celery, 17.66 pounds, $1.13 (183); lettuce, 6.88 pounds, 70 cents (187); onions, 2.59 pounds, 9 cents (189); oyster plant, 2.31 pounds, 20 cents (191); parsnips, 4.59 pounds, 22 cents (191); peas, canned, 6.54 pounds, 63 cents (192); peas, split, 1.09 pounds, 6 cents (195); potatoes, 83.34 pounds, $1.21 (196); potato chips, 1.31 pounds, 38 cents (197); pumpkins, 8 pounds, 20 cents (199); radishes, 1.54 pounds, 20 cents (200); spinach, 1.25 pounds, 15 cents (206); succotash, canned, 2.28 pounds, 18 cents (208); squash, 9.50 pounds, 27 cents (207); potatoes, sweet, 17.48 pounds, 28 cents (198); tomatoes, canned, 10.72 pounds, $1.33 (209); watercress, 0.73 pound, 10 cents (213)	8.54	4.0	8	2	49	216
Fruits, etc.: Apples, 23.25 pounds, 81 cents (214); apricots, dried, 1.69 pounds, 32 cents (217); bananas, 11.83 pounds, 75 cents (218); dates, 3.04 pounds, 20 cents (230); figs, 0.85 pound, 14 cents (231); grapes, Catawba, 13.27 pounds, $1.40 (232); lemons, 6.38 pounds, 40 cents (236); peaches, canned, 2.41 pounds, 19 cents (239); pears, 3.33 pounds, 27 cents (241); prunes, 5.17 pounds, 47 cents (247); raisins, for cooking, 0.35 pound, 3 cents (248); raisins, for table, 0.89 pound, 30 cents (248); jelly, barberry, 1.14 pounds, 9 cents (219); jelly, crabapple, 1.14 pounds, 9 cents (226); jelly, cranberry, 7.31 pounds, 47 cents (228); jelly, grape, 1.48 pounds, 12 cents (233); marmalade, orange, 0.91 pound, 12 cents (237); nuts, hickory, 2.38 pounds, 24 cents (253); English walnuts, 0.44 pound, 18 cents (256); peanuts, 0.97 pound, 6 cents (254)	6.65	3.3	2	3	50	235
Total vegetable food	21.57	10.3	30	14	322	1,533
Total food	59.42	28.1	93	156	349	3,156
Beverages, condiments, etc	3.55	1.7	....	....	....	....

The kitchen and table waste were not weighed during the period of this study, but the nutritive values of the foods were calculated from the average composition of the foods as purchased, which makes allowance for portions which are really not edible. Presumably, then, the figures given above stand for material which might have been consumed entirely if the family had so desired.

It will be noticed that both loaves of bread and bread flour are mentioned. The bread was almost entirely homemade and was on hand ready for use before the observations began. Therefore the bread is estimated as such, rather than reduced to terms of raw materials. As the loaves were not sufficient in number to last through the whole period, flour and other ingredients were weighed in bulk for the remainder of the time and were taken account of accordingly.

DIETARY OF MEDIUM COST (No. 2a).

The experiment with a diet of medium cost, namely, about 25 cents, covered one week only, lasting from January 9 to 15, inclusive. The circumstances were the same as in the preceding case, save that the family numbered only 14 women. The total number of meals eaten was 298, equivalent to 1 woman for 99 days.

The menus for the entire study follow:

Daily menu.

THURSDAY, JANUARY 9.

Breakfast.—Wheat breakfast food,[a] bacon, creamed potatoes, wheat bread.

Luncheon.—Finnan haddie, boiled samp, lettuce salad, gingerbread, full-cream cheese, Russian tea.

Dinner.—Clear turkey-stock soup, roast mutton, escalloped onions, roasted potatoes, apricot ice.

FRIDAY, JANUARY 10.

Breakfast.—Oranges, shredded-wheat biscuit, creamed codfish, baked potatoes, entire-wheat muffins.

Luncheon.—Beef loaf, creamed spaghetti, stewed prunes, toasted Boston crackers, Russian tea.

Dinner.—Baked haddock, egg sauce, mashed potatoes, creamed carrots and canned peas, lettuce salad, salted wafers, apple pie, pale American cheese.

SATURDAY, JANUARY 11.

Breakfast.—Oranges, rolled-oat breakfast food, Finland bloaters, creamed toast, graham muffins.

Luncheon.—Rice and mutton croquettes, escalloped macaroni and tomato, pop-corn brittle, Russian tea.

Dinner.—Split-pea soup, roast veal, Saratoga potatoes, creamed salsify, farina pudding with thin cream.

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[a] Different kinds were used during the study to give variety.

SUNDAY, JANUARY 12.

Breakfast.—Oranges, wheat breakfast food, Boston baked beans, Boston brown bread.

Dinner.—Clear beef-stock soup, roast fowl, dressing, gravy, boiled rice, lettuce salad, frozen-fig pudding, coffee.

Supper.—Creamed veal on toast, bread and butter sandwiches, Norwegian apple pudding with thin cream, cocoa.

MONDAY, JANUARY 13.

Breakfast.—Oranges, wheat breakfast food, codfish balls, corn bread.

Luncheon.—Clam chowder, baked beans and lettuce salad, hot wheat rolls, coffee jelly with thin cream, Russian tea.

Dinner.—Clear chicken soup, roast beef rump, creamed lima beans, roasted potatoes, sliced oranges and bananas, sugar cookies.

TUESDAY, JANUARY 14.

Breakfast.—Bananas, corn-meal mush, creamed dried beef, wheat muffins.

Luncheon.—Escalloped fowl and spaghetti, baked mashed potatoes, hot wheat rolls, German fried toast with foam sauce.

Dinner.—Baked beans and tomato soup, meat pie (made from rump roast), roasted sweet potatoes, lemon sherbet, sugar cookies.

WEDNESDAY, JANUARY 15.

Breakfast.—Oranges, rolled-oat breakfast food, creamed hard-boiled eggs on toast, entire-wheat raised biscuit.

Luncheon.—Cream of lima-bean soup, pork sausages, steamed brown bread, dates and peanuts.

Dinner.—Clear beef-stock soup, beefsteak (rump), boiled samp, escalloped tomato, Spanish pickle, lettuce salad, tapioca cream.

The 11 o'clock luncheon of crackers and milk, served to any who desired it, has been included in the estimate of cost and food values given beyond, though not mentioned in the menu. At breakfast milk, cocoa, and coffee were served, and one of the three was taken by each member of the family. Heavy cream was used with coffee every morning, but at Sunday dinner sugar only was furnished and the coffee was served in small cups. Thin cream was always supplied with the breakfast cereal. When no substitute is mentioned it is understood that cold graham or wheat bread was served at each meal. At breakfast and luncheon butter was served with the bread, but never at dinner. When oranges were served at breakfast, half an orange was given to each person. When bananas were on the morning bill of fare, one was served each member of the family. French dressing always accompanied lettuce.

It was estimated that the diet provided according to the above menus would furnish on an average per woman per day 98 grams of protein, 123 grams of fat, and 348 grams of carbohydrates, and would have a fuel value of 2,878 calories. The estimated cost of the diet (including food accessories), based upon wholesale prices, was 24.8 cents per woman per day.

The details of the study follow.

TABLE 2.—*Weights and cost of food and nutrients in dietary study No. 2a.*

Food consumed during the entire study (7 days).		Cost, nutrients, and fuel value of food per woman per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Rump roast, 7.38 pounds, 99 cents (15); rump steak, 3.78 pounds, 51 cents (30); soup bones, 12.04 pounds (21); soup stock, 5.81 pounds (22), hamburg steak, 3.06 pounds, 30 cents (25); dried beef, 0.72 pound, 20 cents (4); gelatin, 0.13 pound, 19 cents (6). Veal, loin, 12.76 pounds, $1.66 (41). Mutton, leg, 9.57 pounds, $1.29 (48)	5.14	5.2	36	25	....	367
Pork: Bacon, 0.87 pound, 12 cents (55); salt pork, 0.25 pound (65); sausage, 2.66 pounds, 32 cents, (66); lard, 1.33 pounds, 15 cents (62)	.61	.6	2	15	....	142
Poultry: Fowl, 9.69 pounds, $1.45 (75)	1.45	1.5	6	6	....	77
Fish: Finland bloaters, 4.76 pounds, 15 cents (82); haddock, 4.13 pounds, 33 cents (84); salt cod, 1.13 pounds, 15 cents (80); clams (edible portion), 2 pounds, 40 cents (78)	1.03	1.0	8	2	....	50
Eggs, 5.95 pounds, $1.28 (105)	1.28	1.3	3	3	....	39
Butter, 10.31 pounds, $2.61 (106)	2.61	2.7	0.5	41	....	367
Milk, 65.53 pounds, $1.78 (114)	1.78	1.8	10	13	15	216
Cream: Thin, 11 pounds, 88 cents (113); heavy, 3.56 pounds, $1.05 (113)	1.93	1.9	1	12	3	123
Cheese: Full cream, 0.26 pound, 19 cents (111); pale American, 0.25 pound, 4 cents (108)	.23	.2	0.5	1	....	11
Total animal food	16.06	16.2	67	118	18	1,392
VEGETABLE FOOD.						
Cereals: Shredded wheat, 0.60 pound, 8 cents (143); rolled oats, 0.63 pound, 4 cents (131); wheat breakfast food, 0.39 pound, 2 cents (136); wheat breakfast food, 0.43 pound, 4 cents (137); wheat breakfast food, 0.35 pound, 2 cents (138); rice, 0.97 pound, 2 cents (133); flour, bread, 19.39 pounds, 42 cents (122); flour, pastry, 1.63 pounds, 5 cents (125); flour, graham, 0.85 pound, 2 cents (124); flour, entire wheat, 0.50 pound, 2 cents (123); bread, 5.33 pounds, 21 cents (147); rolls, 0.28 pound, 1 cent (159); cookies, sugar, 0.26 pound, 2 cents (152); crackers, Boston, 1.14 pounds, 9 cents (154); wafers, salted, 0.26 pound, 6 cents (161); macaroni, 0.16 pound, 2 cents (127); samp, 0.76 pound, 2 cents (134); spaghetti, 1.10 pounds, 11 cents (135); pop corn, 0.99 pound, 20 cents (132)	1.47	1.5	18	3	119	575
Sugars, starches, and oils: Sugar, cut loaf, 4.57 pounds, 30 cents (163); sugar, granulated, 13.37 pounds, 73 cents (163); sugar, powdered, 0.33 pound, 2 cents (163); molasses, dark, 2.31 pounds, 4 cents (165); cocoa, 0.24 pound, 9 cents (168); oil, cotton-seed, 0.11 pound, 1 cent (170); oil, olive, 1.16 pounds, 30 cents (170); tapioca, 0.24 pound, 1 cent (173)	1.50	1.5	1	6	93	429
Vegetables: Beans, pea, 0.61 pound, 6 cents (177); beans, lima, 1.24 pounds, 10 cents (176); carrots, 1.98 ponnds, 4 cents (182); lettuce, 2.08 pounds, 30 cents (187); onions, 1.44 pounds, 5 cents (189); peas, canned, 1.10 pounds, 11 cents (192); Saratoga potatoes, 0.49 pound, 14 cents (197); potatoes, sweet, 4.55 pounds, 22 cents (198); potatoes, 33.81 pounds, 54 cents (196); salsify, 2.08 pounds, 20 cents (203); tomatoes, 6.31 pounds, 39 cents (211)	2.15	2.2	6	2	38	194
Fruits, nuts, etc.: Apples, 9.49 pounds, 27 cents (214); apricots, 0.72 pound, 14 cents, (216); bananas, 3.75 pounds, 20 cents (218); dates, 1.68 pounds, 11 cents, (230); figs. 0.25 pound, 4 cents (231); lemons, 2.25 pounds, 22 cents (236); oranges, 11.70 pounds, 43 cents (238); prunes, 1.24 pounds, 11 cents (247); peanuts, 0.78 pound, 5 cents (254); English walnuts, 0.25 pound, 10 cents (256)	1.67	1.7	2	2	21	110
Total vegetable food	6.79	6.9	27	13	271	1,308
Total food	22.85	23.1	94	131	289	2,700
Beverages, condiments, etc	0.44	0.4	....	....	....	....

In this study the amount of material rejected in the kitchen and at the table was determined and found to be 15 per cent of the total food purchased. But inasmuch as no distinction was made between refuse, that is, inedible material, and waste, that is, material that could have been eaten but was rejected, no correction for this material has been made in the figures as given in the tables.

According to the final results in the table above, the foods used contained 4 grams less protein, 8 grams more fat, and 59 grams less carbohydrates, and furnished 179 calories less per woman per day than was estimated before the experiment began.

DIETARY OF LOW COST (No. 3a).

The low-cost diet, which was estimated to furnish food at about 17 cents per woman per day, covered only three days, namely, March 12 to 14, inclusive. The average number of persons at the table was 15, and the total number of meals served 137, equivalent to 1 woman for 46 days.

The menus for the three days were as follows:

Daily menu.

WEDNESDAY, MARCH 12.

Breakfast.—Shredded-wheat biscuit, sausages, hominy cakes with lemon sirup, corn bread.

Luncheon.—Codfish loaf with parsley sauce, baked potatoes, stewed prunes, graham rolls.

Dinner.—Split-pea soup, shoulder of mutton (roasted and stuffed), gravy, boiled samp, escalloped tomatoes, graham bread, lemon sherbet.

THURSDAY, MARCH 13.

Breakfast.—Wheat breakfast food, smelts, creamed toast, graham muffins.

Luncheon.—Clear mutton stock soup, beef loaf with brown sauce, steamed brown bread, dates and peanuts.

Dinner.—Beef stew and dumplings, creamed lima beans, boiled rice, sliced bananas dressed with lemon juice and powdered sugar.

FRIDAY, MARCH 14.

Breakfast.—Rolled-oat breakfast food, creamed codfish, fried cornmeal mush, buttered toast.

Luncheon.—Baked beans and tomato soup, macaroni with cheese, German potato salad, wheat rolls, hot gingerbread, Russian tea.

Dinner.—Clear beef stock soup, escalloped haddock, lettuce salad, sweet potato browned in sugar sirup, steamed suet pudding (with dates) and lemon sauce.

The 11 o'clock luncheon of crackers and milk was offered, as usual, to those who cared to take it, and forms part of the amounts that are included in the tables.

The choice of cocoa, coffee, or milk was given each morning at breakfast. The cocoa was made with whole milk, and thin rather than heavy cream was furnished with the coffee, the top of the milk being frequently used, as milk was bought in large quantities. This accounts for the small amount of thin cream recorded in the tables. Whole milk instead of cream was used with the cereals at breakfast, and sugar was always supplied with cereals and hot beverages. When no substitute is mentioned cold wheat or graham bread was served at each meal as usual. Butter was always served at breakfast and luncheon, but not at dinner. Chicken fat was sometimes used instead of butter in cooking. Lettuce was dressed, as usual, with seasoned olive oil and vinegar.

It was estimated that the diet according to the menus proposed would furnish 80 grams of protein, 126 grams of fat, and 348 grams of carbohydrates per woman per day, and have a fuel value of 2,833 calories of energy.

The details of the study are given below.

TABLE 3.—*Weights and cost of food and nutrients in dietary study No. 3a.*

Food consumed during the entire study (3 days).		Cost, nutrients, and fuel value of food per woman per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Round, lower, 3.25 pounds, 33 cents (29); hamburg steak, 3 pounds, 33 cents (25); soup stock, 16 pounds (22); suet, 0.22 pound, 1 cent (35). Mutton, shoulder, 8.75 pounds, 70 cents (52)	1.34	3.0	35	24	....	354
Pork: Sausage, 1.25 pounds, 18 cents (66); lard, 0.18 pound, 1 cent (62)	.19	.4	2	7	....	70
Poultry: Chicken fat, 0.44 pound (73)	....	....	....	4	....	36
Fish: Cod, salt, 1.84 pounds, 24 cents (80); haddock, 3.06 pounds, 27 cents (84); smelts, 2 pounds, 44 cents (101)	.95	2.1	8	....	....	32
Eggs, 1.06 pounds, 15 cents (105)	.15	.3	1	1	....	13
Butter, 3.93 pounds, $1.07 (106)	1.07	2.4	....	34	....	303
Milk, 31.72 pounds, 87 cents (114)	.87	2.0	11	13	16	224
Cream, thin, 0.53 pound, 5 cents (113)	.05	.1	....	1	....	9
Cheese, pale American, 0.16 pound, 2 cents (108)	.02	....	....	....	....	....
Total animal food	4.64	10.3	57	84	16	1,041
VEGETABLE FOOD.						
Cereals: Rice, 0.86 pound, 7 cents (133); corn meal, 1.70 pounds, 5 cents (119); rolled oats, 0.47 pound, 3 cents (131); hominy, 0.42 pound, 1 cent (126); wheat breakfast food, 0.39 pound, 2 cents (138); shredded wheat, 0.58 pound, 7 cents (143); flour, bread, 1.74 pounds, 3 cents (122); flour, graham, 1.48 pounds, 6 cents (124); flour, entire wheat, 0.83 pound, 3 cents (123); bread, wheat, 6.85 pounds, 20 cents (147); samp, 0.60 pound, 2 cents (134); spaghetti, 0.50 pound, 5 cents (135)	.64	1.4	11	2	72	350
Sugars, starches, and oils: Sugar, cut loaf, 0.72 pound, 5 cents (163); sugar, granulated, 7.32 pounds, 33 cents (163); sugar, powdered, 0.28 pound, 1 cent (163); molasses, dark, 2.20 pounds, and molasses, light, 0.89 pound, 5 cents (165); cocoa, 0.08 pound, 2 cents (168); oil, olive, 0.28 pound, 8 cents (171)	.54	1.2	1	3	106	455
Vegetables: Beans, pea, 1.03 pounds, 7 cents (177); beans, lima, 1.20 pounds, 8 cents (176); carrots, 0.26 pound, 1 cent (182); celery, 0.72 pound, 9 cents (183); lettuce, 0.89 pound, 7 cents (187); onions, 0.14 pound, 1 cent (189); parsley, 1 cent; peas, split, 0.44 pound, 1 cent (195); potatoes, sweet, 1.26 pounds, 10 cents (198); potatoes, white, 10.18 pounds, 16 cents (196); tomatoes, canned, 6.75 pounds, 38 cents (209); turnips, 0.88 pound, 4 cents (212)	1.03	2.3	8	2	38	202

Table 3.—*Weights and cost of food and nutrients in dietary study No. 3a*—Continued.

Food consumed during the entire study (3 days).		Cost, nutrients, and fuel value of food per woman per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
VEGETABLE FOOD—continued.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Fruits, nuts, etc.: Bananas, 4 pounds, 19 cents (218); dates, 2 pounds, 10 cents (230); lemons, 1.69 pounds, 9 cents (236); prunes, 1.50 pounds, 7 cents (247); peanuts, 0.66 pound, 4 cents (254)	0.49	1.1	2	3	25	135
Total vegetable food	2.70	6.0	22	10	241	1,142
Total food	7.34	16.3	79	94	257	2,183
Beverages, condiments, etc	.27	.6				

In this experiment the amount of materials rejected in the kitchen and at the table was 11 per cent of the total food purchased; but as it includes both refuse and waste, no deduction can be made for amounts of nutrients wasted.

The food actually supplied during this period furnished practically just the amount of protein, but less than the amounts of the other food elements and energy estimated for the proposed menu.

DIETARY OF HIGH COST (No. 4a).

The most expensive of the four diets, costing 53 cents per person per day, was supplied in a study which covered three days, namely, April 30 to May 2, inclusive. It was especially desired in this case to observe the kind of food for which the unhampered purchaser naturally spends the most money, to discover which of the three nutritive elements, if any, would be used in excess under the circumstances, and to compare the percentage of waste with that observed in the other dietaries of lower cost.

The menus for the three days were as follows:

Daily menu.

WEDNESDAY, APRIL 30.

Breakfast.—Strawberries, shredded-wheat biscuit, broiled bluefish, potato balls with parsley dressing, popovers.

Luncheon.—Fricasseed oysters in croustades, stuffed potatoes, peas, Roman lettuce salad with full cream cheese, coffee.

Dinner.—Clear barley soup, braised fowl with mushroom sauce, boiled rice, asparagus, lettuce salad, cheese wafers, orange bomb glace, angel cake.

THURSDAY, MAY 1.

Breakfast.—Oranges, rolled-oat breakfast food, eggs poached in cream (served on toast), white corn bread.

Luncheon.—Cream of corn soup with popcorn, salmon creams with sauce hollandaise, potato roses, hot graham rolls, strawberry queen of puddings with thin cream.

Dinner.—Victoria (chicken soup), broiled shad roe with maître d'hotel sauce, horseradish sandwiches, roast beef (rump), Yorkshire pudding, roasted potatoes, creamed turnips, June fruit salad, Camembert cheese canapés, coffee.

FRIDAY, MAY 2.

Breakfast.—Grape fruit, wheat breakfast food, rump steak (garnished with water cress), baked potatoes, buttered toast, orange marmalade.

Luncheon.—Cream of asparagus soup, ragoût of duck, lettuce and orange salad, brown bread sandwiches filled with cream cheese and water cress, wheat-bread sandwiches filled with cucumbers dressed with maître d'hotel butter, caramel charlotte russe.

Dinner.—Clear tomato soup, broiled mackerel garnished with lemon and parsley, cucumbers with French dressing, potatoes with maître d'hotel dressing, spinach on toast, chicory salad, cheese croquettes, tutti-frutti ice cream, coffee.

Heavy cream was served with coffee in the morning. Thin cream was furnished with cereals and with strawberries at breakfast, and was used for poaching the eggs. At 11 o'clock a luncheon of milk and crackers not mentioned in the menus was served, and the amounts eaten have been included in the tables. Butter was served at table in the morning and at noon, and was freely used in cooking. When no substitute is mentioned white or graham bread was served at each meal. Plain salads were dressed with seasoned olive oil and vinegar.

The nutritive value of the proposed menu was calculated as usual, but these figures are omitted, as the menu actually served differed very materially from the one on which the calculations were based.

The details of the study follow.

TABLE 4.—*Weights and cost of food and nutrients in dietary study No. 4a.*

Food consumed during whole study (3 days).		Cost, nutrients, and fuel value of food per woman per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Roast, rump, 4.69 pounds, 71 cents (15); steak, rump, 2.7 pounds, 42 cents (30)	1.13	2.7	12	15		182
Pork, etc.: Lard, 0.06 pound (62)				1		9
Poultry: Duck, 3.65 pounds, 73 cents (74); fowl, 6.41 pounds, 96 cents (75)	1.69	4.0	15	17		211
Fish: Bluefish, 2 88 pounds, 35 cents (77); mackerel, 3.5 pounds, 64 cents (92); oysters, 3.1 pounds, 53 cents (93); salmon, 1.63 pounds, 29 cents (95); shad roe, 1.19 pounds, 50 cents (100).	2.31	5.5	15	5	1	109
Eggs, 8.13 pounds, $1.10 (105)	1.10	2.6	10	8		111
Butter, 7.88 pounds, $2.57 (106)	2.57	6.1	1	7		66
Cream: Heavy, 6 pounds, $1.50 (113); thin, 3.19 pounds, 36 cents (113)	1.86	4.4	3	18	5	192
Milk, 36.28 pounds, $1.16 (114)	1.16	2.8	13	16	20	274
Cheese: Plain, 0.35 pound, 5 cents (108); cream, 0.58 pound, 33 cents (111); Camembert, 0.15 pound, 5 cents (109)	.43	1.0	3	4		48
Total animal food	12.25	29.1	72	91	26	1,202

TABLE 4.—*Weights and cost of food and nutrients in dietary study No. 40*—Continued.

Food consumed during whole study (3 days).		Cost, nutrients, and fuel value of food per woman per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
VEGETABLE FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Cereals: Barley, 0.1 pound (116); rice, 0.54 pound, 3 cents (133); flour, bread, 4.72 pounds, 10 cents (122); flour, graham, 2.43 pounds, 6 cents (124); corn meal, yellow, 0.24 pound, 1 cent (120); corn meal, white, 0.49 pound, 2 cents (119); rolled oats, 0.47 pound, 3 cents (131); wheat breakfast food, 0.38 pound, 2 cents (138); shredded wheat, 0.5 pound, 6 cents (143); bread, white, 9.35 pounds, 28 cents (147); bread, graham, 2.21 pounds, 6 cents (145); crackers, Boston, 0.24 pound, 2 cents (154); salted wafers, 0.31 pound, 7 cents (161)	0.76	1.8	24	5	149	737
Sugars, starches, etc.: Sugar, granulated, 5.37 pounds, 29 cents (163); sugar, loaf, 1.44 pounds, 10 cents (163); sugar, powdered, 0.96 pound, 6 cents (163); molasses, 2 pounds, 4 cents (165); olive oil, 1.3 pounds, 33 cents (171); honey, 0.21 pound, 12 cents (164); cocoa, 0.16 pound, 7 cents (168)	1.01	2.4	1	14	101	533
Vegetables: Asparagus, 5.26 pounds, 90 cents (174); corn, canned, 1.3 pounds, 14 cents (184); cucumbers, 3.5 pounds, 50 cents (186); lettuce, 1.55 pounds, 16 cents (187); mushrooms, 0.52 pound, 38 cents (188); onions, 0.69 pound, 2 cents (189); parsley, 5 cents; peas, 3.63 pounds, 28 cents (193); potatoes, 23.48 pounds, 43 cents (196); romaine, 0.81 pound, 25 cents (202); turnips, 3.16 pounds, 10 cents (212); water cress, 0.28 pound, 10 cents (213)	3.31	7.9	17	1	71	361
Fruits, nuts, etc.: Almonds, 0.11 pound, 4 cents (252); candied fruit, 0.94 pound, 32 cents (220); grape fruit, 5.87 pounds, 80 cents (234); bananas, 1.41 pounds, 6 cents (218); lemons, 1.44 pounds, 9 cents (236); oranges, 9.69 pounds, 29 cents (238); orange marmalade, 0.50 pound, 6 cents (237); peanuts, salted, 0.53 pound, 37 cents (255); pineapples, canned, 2.75 pounds, 38 cents (244); strawberries, 5.96 pounds, $1.75 (250)	4.16	9.9	4	4	43	224
Total vegetable food	9.24	22.0	46	24	364	1,855
Total food	21.49	51.1	118	115	390	3,057
Beverages, condiments, etc	1.12	3.0	....	....	....	....

In spite of the fact that the amounts of materials rejected at the table and in the kitchen were as large in this as in either of the other studies, the quantities of nutrients and energy in the food used in this study were still very large, being actually greater than is called for by the common dietary standard for a man at light to moderate muscular work.

CONCLUSIONS.

Two of the experimental studies were carried on for only three days; the other was continued for a week, and the study under the usual conditions for two weeks. It would have been more satisfactory to have made all the studies of at least a week's duration, but it was not practicable. However, the results of the investigations as a whole are quite satisfactory; and while they are not sufficient to warrant final conclusions, some interesting deductions may be drawn from them.

The results of the four studies are summarized in the following table, which includes for the sake of comparison the quantities of nutrients as estimated from the proposed menus in two studies:

TABLE 5.—*Summary of results of dietary studies at Boston School of Housekeeping.*

	Cost.	Protein.	Fat.	Carbohydrates.	Energy.
	Cents.	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Usual diet	28.1	93	156	349	3,156
Diet of medium cost:					
Food estimated	....	98	123	348	2,878
Food served	23.1	94	131	289	2,700
Diet of low cost:					
Food estimated	....	80	126	348	2,833
Food served	16.3	79	94	257	2,183
Diet of high cost	51.1	118	115	390	3,057

The quantity of protein in the diet of the group under the usual conditions of the school was practically the same as that of the commonly accepted standard for women at light to moderate muscular work, but the quantity of energy was more than 25 per cent above that of the standard, owing to the fact that the amounts of fat and carbohydrates in the diet were rather liberal.

As compared with the results of dietary studies made elsewhere, the cost in this study, 28 cents per woman per day, was rather high, especially in view of the fact that much of the food was bought at wholesale rates. In the average of 18 studies of professional men's families made in different parts of the country the diet, which was purchased at retail, cost only 26 cents per man per day, while it supplied 108 grams of protein and 3,300 calories of energy. In seven studies made in New York City the diet, which was believed to be rather expensive, cost on an average, at retail prices, 26 cents per man per day, and furnished 138 grams of protein and 3,747 calories of energy. In a dietary study with a women students' club at North Dakota Agricultural College[a] the cost of the diet was only 14 cents per woman per day, yet the food supplied 70 grams of protein and 2,795 calories of energy per woman per day, and in a study at Lake Erie College[a] food costing 18 cents supplied 78 grams of protein and 2,835 calories of energy per woman per day.

When the expenditure for food was limited to a moderate sum, under the experimental conditions in the studies at the School of Housekeeping, the cost per woman per day was 23 cents, or just 5 cents less than in the study under usual conditions. The food used in this study supplied almost exactly the same quantity of protein, but 450 calories of energy less per woman per day than was found in the regular dietary. As regards the dietary of medium cost, it may be said in general that the meals were pleasing and satisfactory to the family. That they were sufficiently nourishing is shown by their calculated food value as compared with the commonly accepted standard and by the continued good health of the family.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 91.

The results of this study as compared with that of the dietary under usual conditions suggest what it is possible to do in the way of decreasing the cost of the diet by careful planning. The ordinary diet, while not strictly limited in cost, was provided by a person with a general knowledge of the relations between cost and nutritive value; yet the diet of smaller cost was quite as satisfactory and could easily have been made equal to the other in fuel value, as it was in protein, without adding anything to the cost.

In the dietary of low cost the expenditure per woman per day was only 16 cents, and the food supplied only 79 grams of protein and 2,183 calories of energy. These quantities are considerably lower than in either of the preceding studies. The low cost was secured largely by using less expensive food materials than were usually purchased. In some cases the kinds of food were different from those ordinarily used, as for instance cheaper cuts of meat, while in other cases the kinds of food were similar in kind to those to which the family was accustomed, but were of a cheaper grade.

With regard to the daily fare in this study, it may be said that while it was certainly nourishing and was readily accepted by those interested in the experimental side of the work it did not find favor with the larger portion of the family, who had no special interest in the investigation and preferred a more elaborate menu. Assuming that these latter young women are fairly representative as regards their likes and dislikes, it would seem that this grade of food can not be recommended as satisfactory for boarding schools.

Of all the diets the most expensive was the one preferred by those not particularly interested in the experimental side of the study. In this case the food cost 51 cents per woman per day, and the quantity of protein supplied was more than 25 per cent larger than that of the regular dietary, though the quantity of energy was a trifle smaller, owing to the fact that the amount of fat eaten was rather small. The increase in the quantity of protein was due largely to the use of larger quantities of animal foods, such as eggs, dairy products, and various kinds of meat. There is a very common tendency, when the expenditure for food is practically unrestricted, to increase the amounts of this class of food materials, which are all more or less rich in protein, and which are at the same time relatively expensive. These and fancy foods and out-of-season articles always raise the cost of the diet out of proportion to the actual nutritive value.

It will be noticed that in the two studies in which the quantities of nutrients of the proposed diet were estimated these differed somewhat from the quantities in the foods actually used. In both cases there was practically an agreement between the quantities of protein as estimated and as used. In the diet of medium cost the quantities of fat were as close as could be expected, but the amount of carbohydrates in the food used was appreciably smaller than in the estimate. In the diet of low cost the quantities of both fat and carbohydrates in the food used were noticeably smaller than the estimated amounts. These differences are not surprising, nor altogether unexpected, and there are several reasons for them. For instance, it was impossible to anticipate, in every case, the mental effect produced upon the family. The appetites of some were undoubtedly affected by the knowledge that their food was being studied and was of a definite cost. Neither could those making the study know, in detail, the personal tastes and exactions of all the members of the family, and it appeared that they differed widely in their acceptance of certain flavors and methods of serving. It was also impossible to control the amount of muscular exercise taken, and, hence, this was irregular both in character and amount. The possible effect of weather upon appetite was another uncertain factor which must be recognized. These are some of the elements which account for unexpected variations in quantities eaten. The results of the investigation as a whole show plainly the impossibility of providing a universally satisfactory bill of fare, as long as the attitude of people toward their food is so largely a question of personal whim. They do show, however, that it is possible to provide a diet of a definite cost which may vary within rather wide limits and which shall at the same time supply the protein and energy called for by the commonly accepted dietary standards.

A DIETARY STUDY AT THE BOSTON SCHOOL OF HOUSEKEEPING, 1901.

By Susannah Usher, S. B.,
Instructor, Boston School of Housekeeping,
and
Bertha M. Terrill.

INTRODUCTION.

For instruction in the practical application of dietary studies, a class at the Boston School of Housekeeping was required to plan menus for its own meals for one week, the cost of the food materials not to exceed 25 cents per woman per day, and the diet for the week to furnish on the average the daily quantities of nutrients and energy called for by the commonly accepted standard for a woman performing a moderate amount of muscular work, i. e., 90 grams of protein and 2,450 calories of energy. A summary of this experiment which was carried on under the direction of the instructors and fellows of the Boston School of Housekeeping in 1901 has been already published.[a] A detailed account of the work follows:

After the menus had been decided upon and a day for the beginning of the study was fixed, account was taken of all the food materials on hand before the study began. Record was also kept of all those purchased during the week. From the sum of these the quantities left on hand at the close were deducted and the difference taken as the amounts used during the study. None of the foods was analyzed. The nutritive value of all food materials was assumed from the averages for similar articles given in a previous publication of this Office.[b] The percentages of nutrients assumed for the food materials are given in Table 29 of the Appendix.

This study continued seven days during the latter half of April, 1901, the season being cold and very backward. The family or group included in the study consisted of 16 women students. They were not all present at every meal, while at several meals there were guests. As is usual, an account was kept of the number of persons present at each meal, and from such data were calculated the equivalent number of meals for one person and the equivalent number of days. There were 297 meals served, which was equivalent to one woman for ninety-nine days.

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[a] The Cost of Food. Mrs. Ellen H. Richards, Boston, 1901, p. 111.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 28, revised.

DAILY MENUS.

Experience had taught what dishes would be tolerated and what would be refused by the members of the class, and those preparing the menus governed themselves accordingly. The menus selected are given below. Doubtless the absence of some common dishes is due to the preparation of a "black list" by the class a few days before the study began.

SUNDAY.

Breakfast.—Wheat breakfast food,[a] baked beans, brown bread, coffee, cocoa, or milk.

Luncheon.—Brown and white bread sandwiches, sliced oranges, cake, cocoa.

Dinner.—Soup, saltines, roast fowl (stuffed), hominy, cranberries, lettuce salad with French dressing, ice cream, cake.

MONDAY.

Breakfast.—One-half shredded-wheat biscuit, boiled egg, graham muffins, apple sauce, coffee, cocoa, or milk.

Luncheon.—Hashed chicken on toast, fried hominy, cookies, stewed apricots, tea.

Dinner.—Soup with rice, rib-roll roast, Irish potatoes (mashed), tomatoes, lemon jelly, with bananas and nuts.

TUESDAY.

Breakfast.—One-half orange, wheat breakfast food, creamed codfish, corn-meal muffins, coffee, cocoa, or milk.

Luncheon.—Vegetable soup, omelet, brown betty, cream.

Dinner.—Split-pea soup, veal roast, Irish pototoes, creamed onions, lettuce salad, saltines, cottage pudding, chocolate sauce.

WEDNESDAY.

Breakfast.—Wheat breakfast food, cream toast, bacon, baked apples, coffee, cocoa, or milk.

Luncheon.—Irish stew with dumplings, fruit salad, cookies, cocoa.

Dinner.—Chicken soup, roast leg of mutton, potatoes, beets, Norwegian dessert.

THURSDAY.

Breakfast.—One-half orange, wheat breakfast food, hash, dry toast, coffee, cocoa, or milk.

Luncheon.—Creamed potatoes, sausage, raised rolls, nut cake, prunelles, tea.

Dinner.—Soup, chicken and veal pie, peas, orange salad, saltines, cracker pudding, cream.

FRIDAY.

Breakfast.—One-half orange, oatmeal, creamed dried beef, corn cake, coffee, cocoa, or milk.

Luncheon.—Fish chowder, rice and mutton croquettes with tomato sauce, salted peanuts, dates.

Dinner.—Tomato soup, baked haddock, hollandaise sauce, mashed potatoes, lima beans, lettuce salad, saltines, suet pudding, lemon sauce.

SATURDAY.

Breakfast.—One-half orange, wheat breakfast food, fish hash, date muffins, coffee, cocoa, or milk.

Luncheon.—"English monkey" (a sort of cheese soufflé) on toast, vegetable salad, baking-powder biscuit, chocolate.

Dinner.—Bean soup, Hamburg steak, baked potatoes, carrots and peas, lettuce salad, saltines, chocolate pudding with hard sauce.

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[a] Several kinds were used during the study to give variety.

DETAILS OF THE DIETARY STUDY (No. 5a).

The details of the dietary study are given in the following table:

TABLE 6.—*Weights and cost of food and nutrients in dietary study No. 5a.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per woman per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Rib roll, 7 pounds, 88 cents (10); shank, 9 pounds, 45 cents (17); dried, 1.13 pounds, 34 cents (4); suet, 0.44 pound, 2 cents (35); gelatin, 0.13 pound, 10 cents (6). Veal, loin, 4.63 pounds, 60 cents (41). Lamb, leg, 9.06 pounds, $1.18 (54)	3.57	3.6	24	19	....	265
Poultry: Fowl, 14.13 pounds, $1.81 (75)	1.81	1.9	9	8	....	107
Pork: Salt pork, 0.45 pound, 5 cents (65); bacon, 1 pound, 15 cents (55); ham steak, 3.38 pounds, 37 cents (70); sausage, 2 pounds, 24 cents (66); lard, 0.42 pound, 4 cents (62)	.85	.9	4	14	....	141
Fish: Cod, fresh, 4.25 pounds, 26 cents (79); cod, salt, 0.9 pound, 11 cents (80); haddock, 8 pounds, 48 cents (84)	.85	.9	6	....	....	24
Eggs, 7.5 pounds, 85 cents (105)	.85	.9	4	3	....	43
Butter, 12.28 pounds $3.07 (106)	3.07	3.1	....	48	....	427
Milk, 84.7 pounds, $2.31 (114)	2.31	2.3	13	16	19	270
Cream, 3.78 pounds, 44 cents (113)	.44	.4	....	3	1	31
Cheese, 0.33 pound, 5 cents (108)	.05	....	1	1	....	13
Total animal food	13.83	14.0	61	112	20	1,321
VEGETABLE FOOD.						
Cereals: Oatmeal, 0.56 pound, 3 cents (130); wheat breakfast food, 0.56 pound, 7 cents (136); wheat breakfast food, 0.56 pound, 7 cents (137); wheat breakfast food, 0.56 pound, 7 cents (138); wheat breakfast food, 0.56 pound, 7 cents (139); shredded wheat, 0.34 pound, 5 cents (143); wheat breakfast food, 0.56 pound, 7 cents (141); hominy, 1 pound, 3 cents (126); rice, 0.5 pound, 5 cents (133); flour, bread, 27.28 pounds, 67 cents (122); flour, pastry, 4.66 pounds, 11 cents (125); corn meal, 3.69 pounds, 7 cents (119); graham meal, 0.75 pound, 2 cents (124); Boston crackers, 0.91 pound, 7 cents (154); saltines, 1.94 pounds, 29 cents (161)	1.74	1.8	23	4	150	728
Sugars, starches, and oils: Sugar, granulated, 15.59 pounds, 87 cents (163); sugar, powdered, 0.31 pound, 5 cents (163); sugar, lump, 2.63 pounds, 18 cents (163); molasses, 2.75 pounds, 9 cents (165); chocolate, 0.38 pound, 14 cents (167); cocoa, 0.31 pound, 18 cents (168); olive oil, 0.75 pound, 31 cents (171)	1.82	1.8	1	5	94	425
Vegetables: Beans, lima (dry), 0.83 pound, 6 cents (176); beans, pea, 0.7 pound, 6 cents (177); beets, 3.5 pounds, 12 cents (180); carrots, 2.27 pounds, 7 cents (182); lettuce, 7 pounds, $1.25 (187); onions, 2.53 pounds, 7 cents (189); peas, canned, 6 pounds, 45 cents (192); peas, split, 0.56 pound, 5 cents (195); potatoes, 27.21 pounds, 55 cents (196); tomatoes, canned, 4 pounds, 17 cents (209); turnips, 0.55 pound, 1 cent (212)	2.86	2.9	6	1	32	161
Fruits, nuts, etc.: Apples, 9.13 pounds, 27 cents (214); apricots, 0.75 pound, 11 cents (216); bananas, 1.2 pounds, 6 cents (218); cranberries, 1.5 pounds, 9 cents (227); currants, dried, 0.16 pound, 4 cents (229); dates, 2.28 pounds, 11 cents (230); lemons, 3 pounds, 25 cents (236); oranges, 6.75 pounds, 65 cents (238); prunelles, 0.5 pound, 7 cents (246); raisins, 0.31 pound, 3 cents (248); peanuts (meats), 1.69 pounds, 14 cents (255); walnuts (meats), 0.56 pound, 25 cents (257)	2.07	2.1	3	5	21	141
Total vegetable food	8.49	8.6	33	15	297	1,455
Total food	22.32	22.6	94	127	317	2,776
Beverages, condiments, etc. (cost)	.84	.8	....	....	....	....

In planning this dietary the estimates were made for a family of six and were multiplied to suit the existing case. The final results given in the table above agreed very well with the estimates. The meals provided were quite satisfactory. Only two of the persons found any of them wholly unsatisfactory, and all declared that they "bought no more candy than usual;" that is, they did not have any special desire to supplement their diet with extra sweets. This was very gratifying in view of the difference in favor of the cost of this diet as compared with that of their usual fare.

CONCLUSIONS.

Judging by this study it seems fair to say that a reasonably satisfactory dietary of moderate cost, which will supply the necessary nutrients and energy, can be provided when sufficient care is given to planning a menu and selecting the food. It is a matter of common experience that it is easier to provide a diet for a given sum when the family is rather large, since it is possible to buy advantageously when large quantities are purchased and the amount of refuse and kitchen and table waste is believed to be proportionally smaller. Further studies are, of course, needed before general deductions can be drawn, but in view of the facts brought out by the present study in connection with the results of general experience and previous investigations it seems fair to say that the cost of the daily fare may be often diminished by intelligent planning of the menu in such a way that a reasonable proportion of moderate-priced foods is used and other justifiable economies are practiced without making the diet so plain that it is unattractive.

The latter fact has been illustrated on a preceding page of this bulletin (see page 24) in a comparison of the ordinary diet of the school with a diet quite as satisfactory and potentially equal in nutritive value, but costing over 20 per cent less. The present dietary was almost identical in cost and nutritive value with the more economical of the two just referred to.

DIETARY STUDY AT THE BIBLE NORMAL COLLEGE, 1902.

By Bertha M. Terrill,
Professor of Home Economics, Hartford School of Religious Pedagogy.

INTRODUCTION.

In February, 1902, the students of the Bible Normal College, situated then in Springfield, Mass. (now in Hartford, Conn., and affiliated with the Hartford Theological Seminary and designated School of Religious Pedagogy), voted to save a sum of money, which they desired to raise for a special object, by reducing the cost of their table board. They had been paying $3 per week for table board at the time, or very nearly 43 cents per person per day, which of course included the cost of fuel, preparation, and service, estimated to be 10.6 cents per person per day. Learning that it has been found possible to provide a balanced and nourishing diet for 10 cents per man per day for the raw food, they entered eagerly into an experiment with a diet to cost that amount for food materials only, the cost of preparation, etc., to remain the same as before, making the total cost of the daily food as served 20.6 cents per person, or 22.4 cents less than their ordinary diet. There were 30 students interested in this project, and it was planned to continue the investigation three days, as this would suffice to save the $20 desired.

It was believed that the results of a dietary study of the family during this period would be of some value, as showing some of the possibilities of a practical application of the results of nutrition investigations. The meals provided were enjoyed, and at the end of three days, although the desired sum had been saved and there was no longer this incentive, all the persons concerned were sufficiently interested in the trial to ask to have it continued three days longer when they learned that the results for such a period would be of considerable more value from a scientific standpoint than those of a study carried on for three days only. The details of the investigation are given herewith.

METHODS.

The method of conducting the investigation was essentially the same as that usually followed. After a study of the available food supply and the cost of food in the local market, menus were prepared which it was believed would be fairly satisfactory and which would fulfill the requirements as regards cost and nutritive value. The amounts of the various materials which it was calculated would be required during the period were then set aside to be used as needed, the plan being to provide generously of the chief and less expensive dishes, with enough of the more expensive foods to give the needed variety. Whatever material was left at the close of the study was subtracted from the amount provided and the difference was assumed to represent the amount used. Generally speaking, the estimated amounts proved amply sufficient, but it was found necessary during the study to purchase some articles in addition to those planned for, and all such foods were also included in estimating the total amounts eaten.

None of the foods was analyzed. The composition of all but two of the different articles was assumed from average values for similar food materials.[a] The composition of the chocolate candy (fudge) was calculated from that of the materials used in making it, and the composition of apple jelly was taken from a compilation not yet published. The assumed values for the composition of the materials eaten in this study are included in Table 29 of the Appendix.

DAILY MENUS.

The menus for the different days covered by the study were as follows:

SATURDAY, FEBRUARY 8.

Breakfast.—Oatmeal and top of milk, fish cakes, toast (with a little butter), prunes, milk and cereal coffee.

Dinner.—Beef soup, croutons, beans (baked with pork), brown bread, apricot shortcake.

Supper.—Sandwiches (cheese and jelly), white and graham bread (no butter), sliced bananas, milk.

SUNDAY, FEBRUARY 9.

Breakfast.—Corn-meal mush and top of milk, baked beans, buns, milk and cereal coffee.

Dinner.—Split-pea soup and crackers (crisped), potted beef, brown sauce, baked potatoes, bread, rice with milk and sugar.

Supper.—Brown-bread sandwiches (with a little butter), white-bread sandwiches with date and peanut filling without butter, cocoa, popcorn salted.

MONDAY, FEBRUARY 10.

Breakfast.—Oatmeal with top of milk, cream toast, cereal coffee.

Dinner.—Baked-bean soup, crisp crackers, Hamburg steak balls, brown sauce, hominy, turnip, peanuts and dates.

Supper.—Potato and beet salad, gingerbread, cheese, bread, milk.

TUESDAY, FEBRUARY 11.

Breakfast.—Wheat breakfast food and dates, creamed codfish, muffins (with little butter), milk and cereal coffee.

Dinner.—Beef stew with biscuits, bread pudding, bread.

Supper.—Scalloped meat and potato, bread (with butter), prunes, chocolate candy "fudge."

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 28, revised.

WEDNESDAY, FEBRUARY 12.

Breakfast.—Oatmeal with top of milk, hash, corn cake, milk and cereal coffee.

Dinner.—Vegetable soup, croutons, baked stuffed beef's heart, brown sauce, rice, cornstarch blanc mange, caramel sauce.

Supper.—Potato and celery salad, white and graham bread, fried corn-meal mush, sirup.

THURSDAY, FEBRUARY 13.

Breakfast.—Corn-meal mush with top of milk, hashed meat on toast, milk and cereal coffee.

Dinner.—Salt salmon, drawn butter sauce, baked potatoes, parsnips, bread, evaporated apple shortcake.

Supper.—Cold sliced beef's heart, creamed potatoes, cocoa, bread (white and graham), ginger snaps.

DETAILS OF THE DIETARY STUDY (No. 6a).

The family in this experiment consisted of 30 students—26 women and 4 men—ranging in age from 25 to 45 years. Considering the 4 men as equivalent to 5 women as regards food consumption, the family for six days was equivalent to 186 women for one day.

The amounts, cost, and nutrients of the food eaten are given in the table following. The numbers in parentheses following each food material in the table refers to the composition given at the same number in Table 29 in the Appendix.

TABLE 7.—*Weights and cost of food and nutrients in dietary study No. 6a.*

Food consumed during the entire study (6 days).		Cost, nutrients, and fuel value per woman per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Hearts, 11 pounds, 38 cents (7); round, 10.5 pounds, $1.05 (28); rump, 10 pounds, 80 cents (13); shank, fore, 3 pounds (20); brisket (stew), 7.25 pounds, 50 cents (1a)	2.73	1.5	15	19	....	229
Pork: Bacon, 2 pounds, 30 cents (57); salt pork, 2 pounds, 18 cents (64); lard, 1 pound, 12 cents (62)	.60	.3	1	8	....	75
Fish: Cod, salt, 4 pounds, 42 cents (81); salmon, salt, 5 pounds, 40 cents (97)	.82	.4	5	2	....	38
Eggs, 1 pound, 33 cents (105)	.33	.2	....	....	....	....
Butter, 9 pounds, $2.25 (106)	2.25	1.2	....	19	....	169
Cheese, 2 pounds, 30 cents (108)	.30	.2	1	2	....	22
Milk, 210 pounds, $2.70 (114)	2.70	1.4	17	20	26	350
Total animal food	9.73	5.2	39	70	26	883
VEGETABLE FOOD.						
Cereals: Corn meal, 10 pounds, 29 cents (119); pop corn, 1 pound, 5 cents (132); hominy, 1.44 pounds, 5 cents (126); oatmeal, 4.5 pounds, 15 cents (130); rice, 4 pounds, 28 cents (133); graham flour, 10 pounds, 25 cents (124); white flour, 66 pounds, $1.55 (122); crackers, Boston, 0.75 pound, 4 cents (154)	2.66	1.4	27	4	178	856
Sugars, starches, etc.: Sugar, granulated, 20 pounds, $1 (163); molasses, 2.33 pounds, 36 cents (165); cornstarch, 0.33 pound, 2 cents (172); cocoa, 1 pound, 17 cents (168); chocolate, 0.12 pound, 5 cents (167)	1.60	.9	1	1	54	229

TABLE 7.—*Weights and cost of food and nutrients in dietary study No. 6a*—Continued.

Food consumed during the entire study (6 days).		Cost, nutrients, and fuel value per woman per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
VEGETABLE FOOD—continued.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Vegetables: Beans, lima, 2 pounds, 18 cents (176); beans, pea, 2.44 pounds, 10 cents (177); beets, 1.25 pounds, 4 cents (180); cabbage, 5 pounds, 10 cents (181); carrots, 1.25 pounds, 2 cents (182), celery, 2.06 pounds, 10 cents (183); parsnips, 4.69 pounds, 15 cents (191); peas, split, 1.69 pounds, 13 cents (195); potatoes, 80 pounds, $1.47 (196); turnips, 5.5 pounds, 7 cents (212)	2.36	1.3	7	1	41	201
Fruits, nuts, etc.: Apricots, dried, 1.5 pounds, 17 cents (217); bananas, 7 pounds, 30 cents (218); dates, 2 pounds, 12 cents (230); prunes, 2 pounds, 18 cents (247); raisins, 0.25 pound, 2 cents (248); peanuts, 2 pounds, 25 cents (255); crab-apple jelly, 0.2 pound, 3 cents (225)	1.07	.6	1	2	13	74
Total vegetable food	7.69	4.2	36	8	286	1,360
Total food	17.42	9.4	75	78	312	2,243

The cost of the diet, 9.4 cents per woman per day, was just within the limit set, but the quantities of nutrients and energy (75 grams of protein and 2,243 calories) were somewhat smaller than was intended. In planning the menu for the first three days, which was done before the experiment began, special effort was made to provide a diet which would furnish for persons occupied as these were sufficient nutrients and energy, according to the commonly accepted American dietary standard, namely, 90 grams of protein and 2,450 calories of energy per day for a woman at light to moderate work. In arranging the menus for the last three days, which were not in the original plan, time was lacking to make as careful estimates of the quantities of nutrients and energy in the diet provided, and in consequence the actual nutritive value of the food consumed during the latter part of the study, especially as regards carbohydrates and energy, was somewhat smaller than during the first half; so that the average per woman per day for the whole six days was slightly lower than it was desired to have it, and lower than it need have been if the decision to carry on the experiment for six days had been made in time to calculate the entire ration more carefully.

The low cost of the diet in this experiment was made possible by the selection of simple and inexpensive food materials and by reducing the quantities of some foods commonly used rather abundantly, as meat and butter. The plan was, as already explained, to provide generously of the less expensive but nutritious materials, and to include only enough of the more expensive, but not more nutritious articles, to give variety. Most of the students felt quite satisfied with the food. The curtailing of the amount of butter served at the table was considered the greatest deprivation: a small pat, about half the customary size, being served to each where butter is indicated with bread on the menu. Two students, who preferred a hearty breakfast with steak or chops, felt the loss of meat especially. On the other hand, three who were accustomed to a luncheon of crackers during the forenoon omitted it voluntarily, reporting that this was done simply because they felt no need of supplementing the breakfast provided. With these exceptions, it was the opinion of the family that, generally speaking, they would not have noticed any marked change from their usual fare.

The importance from the standpoint of economy of selecting foods which are nourishing rather than those having a low food value but which please the palate and add to the attractiveness of the diet, is illustrated by a dietary study made of a family in New Jersey[a] in which it was found that \$2.16 was expended in three weeks for oranges and \$3 for celery, making a total of \$5.16 for these two articles, which together furnished only 150 grams of protein and 6,445 calories of energy. During the same period \$5.16 was also expended for cereal foods and sugars, which supplied 3,375 grams of protein and 184,185 calories of energy, or about twenty-five times the amount furnished by the oranges and celery. Of course, the sum expended for these articles was not excessive and they undoubtedly helped to make the diet palatable and pleasing, a by no means unimportant consideration, but it is evident that they were not economical sources of nutritive material.

In the present investigation it was found to be well worth while to use special care in arranging the dishes for serving, that they might be as appetizing in appearance as possible, and for the same reason the Sunday evening tea was served from a small table by an open fire. Much care was also observed in avoiding waste both by careful preparation and by the use of all "left overs."

The low cost of the diet was doubtless due in part to the fact that it was made up entirely of home-cooked food, as it has been shown by experiments that food thus prepared under favorable conditions is cheaper than that purchased ready cooked. For instance, in some studies made at the Boston School of Housekeeping,[b] it was found that the average cost of a pound of homemade bread, including materials and fuel for baking, was 3.72 cents, or, considering only the cost of materials, 2.94 cents. A pound of baker's bread cost at this time 5.55 cents. If the labor is included, which was valued at 8.5 cents per hour on the assumption that a cook would receive \$4 per week, the cost of homemade bread was calculated to be 5.87 cents per pound. However, in most cases it would hardly be fair to include this factor.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 35.

[b] Massachusetts Labor Bul., 1901, No. 19, p. 67.

as a cook would be paid the same wages whether the bread was baked at home or not. Furthermore, the cost of fuel may be lessened provided the bread is baked when a fire is required for some other household purpose.

Studies at the same institution with poultry also showed that the home-cooked article was cheaper than that purchased ready cooked.

GENERAL DEDUCTIONS.

The experiment at the Bible Normal College progressed in a very satisfactory manner throughout. The fact that it was possible to live at all comfortably at so low a figure was wholly novel to many of the students, and there was considerable interest and curiosity manifested at each meal. This fact doubtless helped to make the simple fare seem more appetizing than it might have been if continued week after week. All were convinced that the actual cost of many of the staple articles of diet may be made much less than they had supposed. Their attitude toward the experiment was such as to make it of especial value, as they were for the most part quite unprejudiced and frank in criticising the results.

The economy of the diet may be illustrated by comparing the results with those obtained in the study of a medium-cost dietary at the Boston School of Housekeeping. (See page 24.) While the diet in this case, though very simple, was fully equal in nutritive value to that at the School of Housekeeping, furnishing slightly less protein but slightly more energy, the cost in Springfield, where the foods were bought at retail, was only about three-fifths of that in Boston, where many of the articles were obtained at wholesale prices. This affords an excellent illustration of what can be done when it seems desirable to make the cost of the daily fare as low as is consistent with a reasonably palatable diet.

DIETARY STUDIES IN PHILADELPHIA AND CHICAGO, 1892–93.

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AND

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INTRODUCTION.

During the year 1892–93 observations were made, at the instance of the College Settlement Association, of the food consumption and dietary customs of families with small incomes living in those sections of Philadelphia and Chicago in which the work of the Settlements was carried on. The primary purpose of these investigations was to obtain reliable information regarding the diet of the people of those regions, which could be used in the efforts to help them to improve their material condition. While the dietary statistics gathered then are somewhat less complete and perhaps less accurate than those of similar investigations carried on at the present time, they nevertheless give important facts concerning the dietary customs of families of small incomes, and form a valuable contribution to our knowledge concerning the food consumption of people under different circumstances in life.

In a report[a] made by one of us (A. S.) upon the completion of the investigations the nutritive values of the dietaries thus collected were given as estimated according to such data as were then available regarding the composition and fuel value of food materials, the relative food consumption of persons of different age, sex, and occupation, etc.; only four studies, however, were given in detail. Four of the studies were briefly reported in a discussion of dietaries for wage-earners and their families, contributed by one of us (E. H. R.) to a publication of the New Jersey State Board of Health.[b] The remainder have never hitherto been published. In the present report are given the details of all the dietary studies completed at that time except a few in which the statistics were in some respects inadequate. In every case the nutrients and energy of the dietaries have been estimated according to the large amount of analytical and other data accumulated since the studies were made. It is believed that the final results, as here given, are more satisfactory than the earlier estimates, from which they differ somewhat.

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[a] Partial report of Dutton Fellow College Settlement Association, 1892–93.

[b] New Jersey State Board of Health Rpt., 17 (1893), p. 425. See also The Cost of Food, New York, 1901, p. 119.

Since these investigations were carried out numerous others of a similar nature have been made and reported. Previous bulletins of this Office have given accounts of dietary studies made with families living in the thickly congested districts of New York,[a] Pittsburg,[b] and Chicago;[c] studies of the diet of negroes living in straitened circumstances in Virginia and Alabama,[d] and of Spanish-American families of very limited means living in New Mexico.[e] Studies of the diet of poor families were also made in Hartford, under the auspices of the School of Sociology.[f] A number of foreign investigations have been conducted with families of small incomes or living under conditions common to such families. The recent important work of this character by Paton and his associates[g] in Edinburgh, and that by B. S. Rowntree[h] in York, England, are all the more interesting in this connection because the studies were made by the methods followed at the present time in the United States. All these investigations, like that reported in this bulletin, were actuated by a desire to ascertain the conditions under which such families live, in order to find ways to help them to make a wiser use of their resources in securing adequate nourishment. As a whole, the results obtained have, at least in part, justified the hopes of the investigators, and the experience gained has proved of very great value to many housekeepers.

METHOD OF INQUIRY.

In both Philadelphia and Chicago the families among whom the studies were made were selected at random from the neighborhood of the college settlements, but they were believed to be typical of the region in which the settlement work was being carried on. The attempt was made to include in both places as many different nationalities as possible, in order that the results of the studies might have a wider practical application and be more useful.

The data sought in these studies included the nationality, age, sex, and weight of the different members of the family; the number of meals taken by each; the kinds, amounts, and cost of food consumed during a given period, and, so far as possible, the financial and hygienic conditions at the time of the study. Methods had to be devised for the collection of such data. In some cases it was possible for the investigator to enter the homes and gather the statistics personally, while in others dependence had to be placed on the statistics furnished by the families themselves. To facilitate the work during the prosecution of the studies in Philadelphia, questions of a general nature were formulated which it was hoped would elicit the desired information. These were printed in the form of a small account book, the first part of the book being devoted to the questions concerning the family itself, while the remainder was arranged so that the quantity and cost of each food material purchased each day could be entered on the line on which the name of the material was printed. These books proved useful and were also employed in the Chicago studies, and served to lessen the work when the investigator made the entries and to simplify the matter so that there would be as little chance for error as possible when the statistics were recorded by the housekeeper.

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[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 46 and 116.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 52.

[c] U. S. Dept. Agr., Office of Experiment Stations Bul. 55.

[d] U. S. Dept. Agr., Office of Experiment Stations Bul. 71.

[e] U. S. Dept. Agr., Office of Experiment Stations Buls. 40 and 54.

[f] Storrs's Experiment Station Report, 1896.

[g] The Diet of Laboring Classes in Edinburgh.

[h] Poverty: A Study of Town Life, p. 222.

The information gathered in both series of studies was, on the whole, fairly satisfactory, though in several cases where records were kept entirely by the family, some of the statistics recorded were manifestly incorrect. To discover errors the accounts were carefully examined as soon as a study was finished, and questions were asked concerning doubtful entries. In this way explanations and corrections were obtained while the matter was still fresh in mind, and greater accuracy was secured.

The calculations of the results of the studies as given in the present bulletin were made by the same methods as have been noted in previous bulletins reporting studies carried on under the auspices of the Office of Experiment Stations.[a] None of the foods used was analyzed. The composition of nearly all of them was assumed to be that given for similar materials in a former publication of this Office.[b] The composition of a few cooked foods was computed from the composition of the materials used in preparing them and the proportions of each material taken according to a recipe believed to be representative. The percentages of nutrients assumed for any food material used in these studies may be found in Table 29 of the Appendix. The reference numbers in the first column of that table correspond to those given in parentheses following the weight and cost of the food materials in the detail tables of the studies.

The studies as given below have been grouped according to the nationalities of the families, as it was believed this would present the fairest comparison of the results, and, furthermore, it would afford some opportunity for noting in how far the dietary habits of the families of foreign birth or parentage had been modified by residence in the United States.

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[a] See list on cover.

[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 28, revised.

DETAILS OF THE STUDIES IN PHILADELPHIA.

The first half of the year devoted to these investigations was spent in Philadelphia. The work there was done under the auspices of the Philadelphia College Settlement, which, although at that time but recently started, was already in touch with many of the families in the region in which it was located. The helpful attitude of all members of the settlement household and the special kindness of Miss Hancock, a college settlement worker in the neighborhood, secured for the investigator a ready entrance to the homes of the families selected for the studies and insured favorable conditions for the investigation. The attempt was made to establish friendly relations with all the families, and to convince them that the work was undertaken for a useful purpose and not to gratify idle curiosity. That this end was accomplished was shown by the almost uniform readiness with which questions were answered, and by the fact that the people were almost without exception very courteous in every way.

All the investigations in Philadelphia were carried on in the winter season. In the data here reported the families studied included Americans, German, Colored, Irish, Italian-Irish, and German, Russian, and Roumanian Jews. The ways of living of the families made it possible to secure what are regarded as fairly reliable data, a considerable amount of which was recorded by the investigator. In all 25 studies were completed, of which 22 have been considered of sufficient accuracy and completeness to include here. The details of these studies follow.

DIETARY STUDIES OF COLORED FAMILIES (Nos. 7a–11a).

The six dietary studies of which the details are given here were made with colored families.

DIETARY STUDY NO. 7A.

This study was made with a family of two persons, a man and a woman, living in one room, for which they paid 80 cents per week. Their income was about $2.50 per week during the winter season, at which time this study was made. The woman was weak and afflicted with neuralgia. In addition to the food materials included in the table they spent 6 cents for coffee, 8 cents for tea, and 1 cent for pot herbs.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Total number of meals equivalent to	38

Equivalent to one man thirteen days.

DIETARY STUDY NO. 8A.

This family consisted of one man, one woman, and a child 5 years old, all healthy. They rented two rooms for which they paid $1.40 per week.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 5 years old (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	46

Equivalent to one man fifteen days.

DIETARY STUDY NO. 9A.

This family consisted of one man, four women, and four children, aged, respectively, 10, 8, 3 years, and 4 months; the latter was not included in the study. They paid $20 per month rent for six rooms. In addition to the food materials included in the table, they spent $2.29 for sundries during the time of the study.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Four women (84 meals × 0.8 meal of man), equivalent to	67
Child, 10 years (21 meals × 0.6 meal of man), equivalent to	13
Child, 8 years (21 meals × 0.5 meal of man), equivalent to	11
Child, 3 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	120

Equivalent to one man forty days.

DIETARY STUDY NO. 10A.

This family consisted of one man, one woman, and five children, aged, respectively, 11, 9, 7, 5, and 3 years. They were all in fairly good health. They paid $12 a month for three rooms. In addition to the food materials purchased they spent 18 cents for tea during the study.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 11 years (21 meals × 0.6 meal of man), equivalent to	13
Two children, 9 and 7 years (42 meals × 0.5 meal of man), equivalent to	21
Two children, 5 and 3 years (42 meals × 0.5 meal of man), equivalent to	17
Total number of meals equivalent to	89

Equivalent to one man twenty-nine days.

DIETARY STUDY NO. 11A.

This family consisted of two women, both strong and well. They rented two rooms for $1.65 a week. One woman did washing. In addition to the foods purchased they spent during the study 16 cents for tea and 5 cents for coffee.

The study continued two days. The number of meals taken was 12, equivalent to 10 meals of a man, or equivalent to one man three days.

TABLE 8.—*Weights and cost of food and nutrients in dietary studies of colored families in Philadelphia.*

Food consumed during the whole study (7 days).	Cost, nutrients, and fuel value of food per man per day.					
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 7a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Pork: Bacon, 0.25 pound, 3 cents (55); shoulder, smoked, 0.5 pound, 7 cents (68); scrapple, 0.5 pound, 4 cents (67); sausage, 1.9 pounds, 27 cents (66)	0.41	3.2	12	43	9	467
Mutton: Sheep's liver, 1 pound, 5 cents (49); neck, 1.5 pounds, 11 cents (50), chops, 0.25 pound, 2 cents (46)	.18	1.4	16	16	2	214
Butter, 0.13 pound, 5 cents (106)	.05	.4	....	4	....	36
Total animal food	.64	5.0	28	63	11	717
VEGETABLE FOOD.						
Cereals: Pudding, 1 pound, 10 cents (258); bread, 7.9 pounds, 31 cents (147)	.41	3.2	27	5	157	781
Vegetables: Beans, 0.95 pound, 5 cents (177); potatoes, 3.5 pounds, 6 cents (196)	.11	.9	10	1	42	217
Total vegetable food	.52	4.1	37	6	199	998
Total food	1.16	9.1	65	69	210	1,715
Dietary study No. 8a.						
ANIMAL FOOD.						
Beef: Round steak, 1 pound, 15 cents (28)	.15	1.0	6	3	....	50
Pork: Ham, 8 pounds, $1.26 (60); sausage, 1 pound, 15 cents (66)	1.41	9.4	38	91	3	1,001
Oysters, 1.5 pounds, 35 cents (93)	.35	2.3	3	1	2	29
Butter, 0.5 pound, 20 cents (106)	.20	1.3	....	13	....	116
Milk, 4 pounds, 16 cents (114)	.16	1.1	4	5	6	85
Total animal food	2.27	15.1	51	116	11	1,281

TABLE 8.—*Weights and cost of food and nutrients in dietary studies of colored families in Philadelphia*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 8a—Continued.						
VEGETABLE FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Cereals: Bread, 4.5 pounds, 20 cents (147); rice, 1 pound, 12 cents (133)	0.32	2.1	15	2	96	462
Sugar, 3 pounds, 18 cents (163)	.18	1.2	....	....	91	364
Vegetables: Cabbage, 13.6 pounds, 55 cents (181); sweet potatoes, 7 pounds, 16 cents (198); potatoes, 7 pounds, 16 cents (196)	.87	5.8	13	2	105	490
Fruit: Apples, 9 pounds, 33 cents (214)	.33	2.2	1	1	29	129
Total vegetable food	1.70	11.3	29	5	321	1,445
Total food	3.97	26.4	80	121	332	2,726
Dietary study No. 9a.						
ANIMAL FOOD.						
Beef: Porterhouse, 3.15 pounds, 70 cents (27); shoulder, 4 pounds, 40 cents (19). Veal, chuck, 4 pounds, 68 cents (37). Mutton: Sheep's liver, 2.5 pounds, 20 cents (49)	1.98	5.0	28	15	1	250
Pork: Bacon, 4 pounds, 56 cents (55); ham, 12 pounds, $1.20 (60); lard, 2.5 pounds, 25 cents (62)	2.01	5.0	24	101	....	995
Fish: Cod, 3 pounds, 30 cents (79); mackerel, 2 pounds, 28 cents (91)	.58	1.4	5	1	....	29
Chicken, 4.2 pounds, 76 cents (75)	.76	1.9	7	6	....	81
Eggs, 3 pounds, 60 cents (105)	.60	1.5	4	4	....	52
Butter, 2.13 pounds, 70 cents (106)	.70	1.8	....	20	....	178
Milk, 16.75 pounds, 64 cents (114)	.64	1.6	6	8	10	135
Total animal food	7.27	18.2	74	155	11	1,720
VEGETABLE FOOD.						
Cereals: Barley, pearled, 1 pound, 5 cents (116); rice, 8 pounds, 64 cents (133); hominy, 4 pounds, 20 cents (126); oatmeal, 3 pounds, 10 cents (130); flour, 12 pounds, 40 cents (122); bread, 3 pounds, 15 cents (147); pie, 2 pounds, 20 cents (158)	1.74	4.4	35	7	269	1,278
Sugar, 10 pounds, 50 cents (163)	.50	1.3	....	....	113	452
Vegetables: Potatoes, 28 pounds, 40 cents (196); sweet potatoes, 7 pounds, 10 cents (198); canned tomatoes, 3.75 pounds, 20 cents (209), turnips, 6.25 pounds, 10 cents (212); cabbage, 1.75 pounds, 8 cents (181); beans, 1 pound, 10 cents (177)	.98	2.4	14	2	89	430
Total vegetable food	3.22	8.1	49	9	471	2,160
Total food	10.49	26.3	123	164	482	3,880
Waste: Steak, 1 pound (27); shoulder, 3.9 pounds (19) potatoes, 2.5 pounds (196); sweet potatoes, 6.3 pounds (198)	....	....	13	8	20	203
Total food eaten	....	....	110	156	462	3,677
Dietary study No. 10a.						
ANIMAL FOOD.						
Beef: Shoulder, 1.5 pounds 16 cents (19); steak, 1.75 pounds, 26 cents (32); roast, 1 pound, 18 cents (12)	.60	2.1	12	9	....	128
Pork: Chops, 1 pound, 14 cents (58); scrapple, 2 pounds, 12 cents (67)	.26	.9	3	10	3	113
Turkey, 8.3 pounds, $1.50 (76)	1.50	5.2	21	24	....	298
Fish: Whitefish, 3 pounds 15 cents (103); smelts, 1.5 pounds, 15 cents (101)	.30	1.0	7	2	....	46
Butter, 0.88 pound, 35 cents (106)	.35	1.2	....	11	....	98
Milk, 7.3 pounds, 28 cents (114)	.28	1.0	4	5	6	85
Total animal food	3.29	11.4	47	61	9	768

TABLE 8.—*Weights and cost of food and nutrients in dietary studies of colored families in Philadelphia*—Continued.

Food consumed during the whole study (7 days).	Cost, nutrients, and fuel value of food per man per day.					
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 10a—Continued.						
VEGETABLE FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Cereals: Bread, 12 pounds, 60 cents (147); pudding, 1 pound, 6 cents (258); rice, 1.5 pounds, 12 cents (133); rolled avena, 3.75 pounds, 21 cents (131); hominy, 1 pound, 5 cents (126)	1.04	3.6	31	8	175	895
Sugar, 3.25 pounds, 20 cents (163)	.20	.7			51	204
Vegetables: Potatoes, 3.5 pounds, 8 cents (196); sweet potatoes, 1.9 pounds, 5 cents (198); canned tomatoes, 1.75 pounds, 10 cents (209)	.23	.8	2		17	76
Fruits: Apples, 3.5 pounds, 20 cents (214)	.20	.7			6	24
Total vegetable food	1.67	5.8	33	8	249	1,199
Total food	4.96	17.2	80	69	258	1,967
Dietary study No. 11a.						
ANIMAL FOOD.						
Mutton: Liver, 2 pounds, 8 cents (49)	.08	2.7	70	27	15	580
Pork: Sausage, 0.75 pound, 11 cents (66); salt pork, 0.5 pound, 7 cents (64)	.18	6.0	16	115	12	1,136
Butter, 0.13 pound, 5 cents (106)	.05	1.7		16		142
Milk, 2.1 pounds, 8 cents (114)	.08	2.6	10	13	16	220
Total animal food	.39	13.0	96	171	43	2,078
VEGETABLE FOOD.						
Cereals: Bread, 3.38 pounds, 15 cents (147)	.15	5.0	47	7	271	1,334
Sugar, 0.5 pound, 2 cents (163)	.02	.7			76	304
Vegetables: Beans, 1 pound, 5 cents (177); onions, 1.9 pounds, 5 cents (189); potatoes, 1.75 pounds, 3 cents (196)	.13	4.3	43	4	162	856
Beer, 2 pounds, 10 cents (259)	.10	3.3	1		35	144
Total vegetable food	.40	13.3	91	11	544	2,638
Total food	.79	26.3	187	182	587	4,716

DIETARY STUDIES OF ITALIAN FAMILIES (Nos. 12a–13a).

The details of two dietary studies of Italian families follow.

DIETARY STUDY NO. 12A.

There were four members of the family in this study—a man, a woman, a boy 3 years old, and a nursing baby, but the latter was not included in the study. They rented a house of six rooms for $16 a month, but sublet four of the rooms for $13. Their weekly income was $7.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 3 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	46

Equivalent to one man fifteen days.

DIETARY STUDY NO. 13A.

This study was made with a family of two women—the mother, aged 60, and her daughter. They owned their own house, consisting of three rooms and a cellar, which would rent for about $9 a month. In addition to the foods purchased they spent during the study 35 cents for coffee and 4 cents for herbs.

The study continued seven days. The number of meals taken was 42, equivalent to 34 meals of a man, or equivalent to one man eleven days.

TABLE 9.—*Weights and cost of food and nutrients in dietary studies of Italian families in Philadelphia.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 12a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Shoulder, 3.5 pounds, 25 cents (19); bologna, 0.5 pound, 6 cents (1). Mutton: Shoulder, 2.5 pounds, 10 cents (51)	0.41	2.7	22	33	....	382
Pork: Chops, 2 pounds, 28 cents (58); lard, 2 pounds, 24 cents (62)	.52	3.5	8	76	....	708
Fish: Sardines, 0.3 pound, 5 cents (99)	.05	.3	2	1	....	17
Eggs, 0.5 pound, 10 cents (105)	.10	.7	2	2	....	26
Milk, 5.23 pounds, 20 cents (114)	.20	1.3	5	6	8	105
Cheese, 0.5 pound, 15 cents (108)	.15	1.0	4	5	....	61
Total animal food	1.43	9.5	43	123	8	1,299
VEGETABLE FOOD.						
Cereals: Bread, 12 pounds, 50 cents (147); flour, 2 pounds, 5 cents (122); macaroni, 1.5 pounds, 15 cents (127)	.70	4.6	46	6	272	1,325
Sugar, 4 pounds, 22 cents (163)	.22	1.5	....	....	121	484
Vegetables: Cabbage, 2.75 pounds, 9 cents (181); onions, 2.75 pounds, 5 cents (189); potatoes, 3.5 pounds, 6 cents (196); tomatoes, canned, 3.34 pounds, 30 cents (209); beans, 0.95 pound, 10 cents (177)	.60	4.0	12	1	52	265
Fruit: Apples, 3.25 pounds, 6 cents (214)	.06	.4	....	....	10	40
Beer, 4 pounds, 40 cents (259)	.40	2.7	1	....	14	60
Total vegetable food	1.98	13.2	59	7	469	2.174
Total food	3.41	22.7	102	130	477	3,473
Dietary study No. 13a.						
ANIMAL FOOD.						
Beef: Shoulder, 2.5 pounds, 25 cents (19); tripe, 5 pounds, 30 cents (72)	.55	5.0	41	11	....	262
Pork: Sausage, 1 pound, 16 cents (66)	.16	1.4	5	18	....	180
Fish: Whitefish, 3 pounds, 25 cents (103); oysters, 1 pound, 25 cents (93)	.50	4.5	16	4	1	104
Eggs, 3 pounds, 56 cents (105)	.56	5.1	16	12	....	171
Butter, 1 pound, 37 cents (106)	.37	3.4	....	35	....	312
Cheese, 0.7 pound, 25 cents (111)	.25	2.3	8	10	1	125
Milk, 3.66 pounds, 14 cents (114)	.14	1.3	5	6	8	105
Total animal food	2.53	23.0	91	96	10	1.259
VEGETABLE FOOD.						
Cereals: Bread, 5 pounds, 25 cents (147); cake and pastry, 0.47 pound, 15 cents (150); macaroni, 2 pounds, 15 cents (127)	.55	4.5	31	5	184	905
Vegetables: Onions, 0.8 pound, 2 cents (189); potatoes, 3.5 pounds, 12 cents (196); canned tomatoes, 1.75 pounds, 12 cents (209)	.26	2.4	4	1	27	133
Fruits: Apples, 5.75 pounds, 30 cents (214); oranges, 5 cents (238)	.35	3.2	1	1	26	117
Beer, 2.5 pounds, 25 cents (259)	.25	2.3	....	....	12	48
Total vegetable food	1.41	12.4	36	7	249	1,203
Total food	3.94	35.4	127	103	.259	2,462

DIETARY STUDIES OF JEWISH FAMILIES (Nos. 14a–18a).

The details of five studies with Jewish families follow. Studies Nos. 14a, 17a. and 18a were with German Jews, No. 15a with Russian Jews, and No. 16a with Roumanian Jews.

DIETARY STUDY NO. 14A.

The members of this family consisted of three men, three women, and one girl 13 years old. They were all in good health. They lived in four rooms, for which they paid $1.75 per week. The income of the family during the time of the study was given as $6.50, which was $1.69 less than the amount spent for food.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Three men	63
Three women (63 meals × 0.8 meal of man), equivalent to	50
Girl, 13 years (21 meals × 0.7 meal of man), equivalent to	15
Total number of meals equivalent to	128

Equivalent to one man forty-three days.

DIETARY STUDY NO. 15A.

This family consisted of three men, one woman, and four children, aged, respectively, 10, 6, 3, and 1½ years. They paid $25 a month rent. In addition to the foods purchased they spent 60 cents for coffee, 14 cents for tea, 5 cents for vinegar, and 4 cents for cinnamon during the course of the study.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Three men	63
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 10 years (21 meals × 0.6 meal of man), equivalent to	13
Child, 6 years (21 meals × 0.5 meal of man), equivalent to	11
Child, 3 years (21 meals × 0.4 meal of man), equivalent to	8
Child, 2½ years (21 meals × 0.3 meal of man), equivalent to	6
Total number of meals equivalent to	118

Equivalent to one man thirty-nine days.

DIETARY STUDY NO. 16A.

The family in this study comprised one man, one woman, and five children, aged, respectively, 10, 8, 6, 4, and 2 years. They paid $11 a month rent for four rooms. In addition to the foods purchased they spent 32 cents for tea and coffee, and 11 cents for pepper and salt during the time of the study.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 10 years (21 meals × 0.6 meal of man), equivalent to	13
Two children, 9 and 6 years (42 meals × 0.5 meal of man), equivalent to	21
Two children, 4 and 2 years (42 meals × 0.4 meal of man), equivalent to	17
Total number of meals equivalent to	89

Equivalent to one man thirty days.

DIETARY STUDY NO. 17A.

The members of this family consisted of a man, a woman, and a baby five months old, which was not included in the study. They paid $4 a month for the rent of two rooms. During the course of the study they spent 59 cents for coffee, tea, chicory, and soda water.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Total number of meals equivalent to	38

Equivalent to one man thirteen days.

DIETARY STUDY NO. 18A.

The members of this family consisted of a man, a woman, and four children, aged, respectively, 11, 8, 5, and 3 years. They paid $8 a month rent for four rooms, one of which was used as a tailor shop. The members of the family were healthy. During the study they spent 10 cents for coffee, 6 cents for chicory, 10 cents for soda water, and 1 cent for salt, in addition to the food materials purchased.

The study continued seven days. The number of meals taken was as follows:

	Meals
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 11 years (21 meals × 0.6 meal of man), equivalent to	13
Child, 8 years (21 meals × 0.5 meal of man), equivalent to	11
Two children, 5 and 3 years (42 meals × 0.4 meal of man), equivalent to	17
Total number of meals equivalent to	79

Equivalent to one man twenty-six days.

TABLE 10.—*Weights and cost of food and nutrients in dietary studies of Jewish families in Philadelphia.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 14a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Shoulder, 20 pounds, $1.98 (19); suet, 1 pound, 8 cents (35)	2.06	4.8	4	10	....	105
Chicken, 3.9 pounds, 70 cents (75)	.70	1.6	6	5	....	69
Fish, white fish, 3 pounds, 25 cents (103)	.25	.6	3	1	....	21
Eggs, 0.5 pound, 10 cents (105)	.10	.2	1	1	....	13
Butter, 1 pound, 38 cents (106)	.38	.9	....	9	....	80
Milk, 13.9 pounds, 50 cents (114)	.50	1.2	5	6	7	101
Cheese, 1.5 pounds, 12 cents (108)	.12	.3	4	5	....	61
Total animal food	4.11	9.6	23	37	7	450
VEGETABLE FOOD.						
Cereals: Rice, 5.5 pounds, 42 cents (133); flour, 7 pounds, 22 cents (122); bread, 39.4 pounds, 1.75 cents (147)	2.39	5.6	51	6	322	1,545
Sugar, 8 pounds, 41 cents (163)	.41	.9	....	....	84	336
Vegetables: Potatoes, 5.25 pounds, 13 cents (196); onions, 4.1 pounds, 15 cents (189); beans, 1.9 pounds, 10 cents (177); cabbage, 1.6 pounds, 5 cents (181); beets, 1.5 pounds, 5 cents (180)	.48	1.1	7	1	28	149
Fruits: Bananas, 10 pounds, 20 cents (218); oranges, 0.4 pound, 10 cents (238); apples, 4.5 pounds, 10 cents (214); prunes, 4 pounds, 40 cents (247)	.80	1.9	2	....	47	196
Total vegetable food	4.08	9.5	60	7	481	2,226
Total food	8.19	19.1	83	44	488	2,676
Dietary study No. 17a.						
ANIMAL FOOD.						
Beef: Shoulder, 7 pounds, 70 cents (19); liver, 0.5 pound, 3 cents (8); bologna, 0.5 pound, 6 cents (1)	.79	6.1	47	25	....	411
Fish: White fish, 1.5 pounds, 10 cents (103); herring, 5 pounds, 9 cents (88); sardines, 0.3 pound, 5 cents (99)	.24	1.8	11	4	....	80
Eggs, 1.13 pounds, 23 cents (105)	.23	1.8	5	4	....	56
Butter, 0.75 pound, 34 cents (106)	.34	2.6	....	22	....	196
Milk, 7.6 pounds, 29 cents (114)	.29	2.2	9	11	13	186
Cheese, 2 pounds, 11 cents (111)	.14	1.1	18	23	2	285
Total animal food	2.03	15.6	90	89	15	1,214
VEGETABLE FOOD.						
Cereals: Hominy, 1.5 pounds, 8 cents (126); flour, 1 pound, 3 cents (122); buns, 2.15 pounds, 15 cents (149); cakes, 0.25 pound, 2 cents (157); bread, 11.75 pounds, 48 cents (147); crackers, 1 pound, 6 cents (153)	.82	6.3	54	15	343	1,722
Sugar, 4 pounds, 22 cents (163)	.22	1.7	....	....	139	556
Vegetables, dried peas, 0.9 pound, 4 cents (193)	.04	.3	8	3	20	139
Fruit: Apples, 1.25 pounds, 4 cents (214)	.04	.3	....	....	5	20
Total vegetable food	1.12	8.6	62	18	507	2,437
Total food	3.15	24.2	152	107	522	3,651
Dietary study No. 18a.						
ANIMAL FOOD.						
Beef: Shoulder, 9.5 pounds, 95 cents (19); suet, 2 pounds, 16 cents (35); bologna, 0.5 pound, 6 cents (1)	1.17	4.5	31	44	....	516
Fish: Sardines, 0.6 pound, 12 cents (99)	.12	.5	2	1	....	17
Butter, 0.5 pound, 20 cents (106)	.20	.8	....	8	....	71
Milk, 10.5 pounds, 40 cents (114)	.40	1.5	6	7	9	122
Cheese: Neufchatel, 1 pound, 16 cents (112)	.16	.6	3	5	....	57
Total animal food	2.05	7.9	42	65	9	783

TABLE 10.—*Weights and cost of food and nutrients in dietary studies of Jewish families in Philadelphia*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
	Dollars.	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Dietary study No. 18a—Continued.						
VEGETABLE FOOD.						
Cereals: Bread, 26.5 pounds, $1.17 (147); crackers, 1 pound, 8 cents (153); cake, 0.5 pound, 5 cents (150); ginger cakes, 0.5 pound, 4 cents (157); hominy, 3 pounds, 9 cents (126); rice, 0.25 pound, 2 cents (133); flour, 4 pounds, 12 cents (122)	1.59	6.1	58	10	367	1,789
Sugar, 9 pounds, 51 cents (163)	.51	2.0	....	....	157	628
Vegetables: Potatoes, 1.75 pounds, 3 cents (196); onions, 1.9 pounds, 5 cents (189); beans, 2.5 pounds, 12 cents (177); dried peas, 0.5 pound, 3 cents (193)	.23	.9	13	1	39	217
Fruits, etc.: Apples, 7.9 pounds, 20 cents (214); bananas, 3 pounds, 5 cents (218); oranges, 4.6 pounds, 12 cents (238); raisins, 0.4 pound, 3 cents (248); prunes, dried, 0.3 pound, 5 cents (247); peanuts, 0.25 pound, 3 cents (254); jelly, 0.5 pound, 3 cents (235)	.51	2.0	2	2	43	198
Total vegetable food	2.84	11.0	73	13	606	2,832
Total food	4.89	18.9	115	78	615	3,615
Dietary study No. 15a.						
ANIMAL FOOD.						
Beef: Shoulder, 17 pounds, $1.75 (19); chopped meat, 4 pounds, 44 cents (25). Veal, 2 pounds, 16 cents (37)	2.35	6.0	18	23	1	401
Eggs, 0.9 pound, 30 cents (105)	.30	.8	1	1	....	13
Butter, 3 pounds, $1.08 (106)	1.08	2.8	....	30	....	267
Milk, 14.6 pounds, 56 cents (114)	.56	1.4	6	7	9	122
Cheese: Neufchatel, 0.75 pound, 15 cents (112)	.15	.4	2	2	....	26
Total animal food	4.44	11.4	57	63	10	829
VEGETABLE FOOD.						
Cereals: Bread, 17.25 pounds, 92 cents (147); barley, 1 pound, 5 cents (116)	.97	2.5	20	3	115	567
Sugar, 6 pounds, 34 cents (163)	.34	.9	....	....	70	280
Vegetables: Potatoes, 14 pounds, 32 cents (196); onions, 2.75 pounds, 12 cents (189); carrots, 3 pounds, 10 cents (182); cabbage, 2.6 pounds, 12 cents (181); beans, 0.9 pound, 5 cents (177); turnips, 3.1 pounds, 8 cents (212); canned peas, 1.9 pounds, 30 cents (192)	1.09	2.8	8	1	48	233
Fruits: Jelly, 0.5 pound, 6 cents (222); apples, 4.5 pounds, 10 cents (214); cranberries, 5 pounds, 72 cents (227)	.88	2.3	....	....	15	60
Total vegetable food	3.28	8.5	28	4	248	1,140
Total food	7.72	19.9	85	67	258	1,969
Dietary study No. 16a.						
ANIMAL FOOD.						
Beef: Shoulder, 21 pounds, $2.10 (19)	2.10	7.0	52	27	....	448
Fish: Whitefish, 3 pounds, 21 cents (103); smoked herring, 0.16 pound, 3 cents (88)	.24	.8	6	2	....	42
Eggs, 0.9 pound, 20 cents (105)	.20	.7	2	1	....	17
Butter, 0.25 pound, 10 cents (106)	.10	.3	....	3	....	27
Milk, 7.8 pounds, 20 cents (114)	.28	.9	4	5	6	85
Cheese: Neufchatel, 0.25 pound, 4 cents (112)	.04	.1	1	1	....	13
Total animal food	2.96	9.8	65	39	6	632

TABLE 10.—*Weights and cost of food and nutrients in dietary studies of Jewish families in Philadelphia*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 16a—Continued.						
VEGETABLE FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Cereals: Corn meal, 1 pound, 5 cents (119); flour, 7 pounds, 21 cents (122); rice, 2 pounds, 14 cents (133); barley, 0.25 pound, 2 cents (117); bread, 39.4 pounds, $1.75 (147)	2.17	7.2	71	9	434	2,100
Sugar, 4 pounds, 22 cents (163)	.22	.7	....	....	60	240
Vegetables: Beans, 7.85 pounds, 33 cents (177); onions, 2.75 pounds, 12 cents (189); potatoes, 3.5 pounds, 8 cents (196)	.53	1.8	28	2	84	466
Fruits: Apples, 2.25 pounds, 6 cents (214); oranges, 1.1 pounds, 27 cents (238); prunes, 1 pound, 12 cents (247)	.45	1.5	1	....	15	64
Total vegetable food	3.37	11.2	100	11	593	2,870
Total food	6.33	21.0	165	50	599	3,502

DIETARY STUDIES OF GERMAN FAMILIES (Nos. 19a–24a).

The details of six studies with German families follow. In one study (No. 24a) the man was native German but the woman was American born.

DIETARY STUDY NO. 19A.

The family in this study lived in the outskirts of the city. There were five persons in the group in the study—two men, one woman, and two children—who were taken to board. The ages of the children were not given; it has been here assumed that they averaged 6 to 7 years. They rented five rooms, for which they paid $9 a month. During the course of the study they spent 5 cents for tea and 60 cents for coffee in addition to the purchase of food materials.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Two men	42
Woman (21 meals × 0.8 meal of man), equivalent to	17
Two children (42 meals × 0.5 meal of man), equivalent to	21
Total number of meals equivalent to	80

Equivalent to one man twenty-seven days.

DIETARY STUDY NO. 20A.

The members of this family comprised one man, one woman, and four children aged, respectively, 8, 6, and 4 years, and 17 months. The father was a fish peddler. They were all in poor health, dispirited, and seemed to be insufficiently nourished. The woman appeared to be shiftless and incapable of improvement. They rented two rooms, for which they paid $4 per month. Their income was variable, being $3 during the week of the study. In addition to the food materials purchased they spent 10 cents for tea, 22 cents for coffee, and 1 cent for pepper.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Two children, 8 and 6 years (42 meals × 0.5 meal of man), equivalent to	21
Child, 4 years (21 meals × 0.4 meal of man), equivalent to	8
Child, 17 months (21 meals × 0.2 meal of man), equivalent to	4
Total number of meals equivalent to	71

Equivalent to one man twenty-four days.

DIETARY STUDY NO. 21A.

This family consisted of two men, one woman, and four children aged, respectively, 11, 8, 6, and 2 years. They were all healthy. They rented a house of four rooms, for which they paid $9 a month. In addition to the food materials purchased they spent 30 cents for coffee during the study.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Two men	42
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 11 years (21 meals × 0.6 meal of man), equivalent to	13
Two children, 9 and 6 years (42 meals × 0.5 meal of man), equivalent to	21
Child, 2 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	101

Equivalent to one man thirty-four days.

DIETARY STUDY NO. 22A.

This family was dirty but healthy. It consisted of a man, a woman, a boy of 16, and two children 14 and 10 years of age. The man and woman had lived in this country twenty-six years. They paid $18 a month rent for nine rooms, including a little tobacco shop at the front of the house. The woman took care of the shop during the day, as the man worked away from home. During the course of the study they spent 90 cents for tea and coffee and 4 cents for yeast cakes in addition to the food materials purchased.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Boy, 16 years old	21
Child, 14 years (21 meals × 0.7 meal of man), equivalent to	15
Child, 10 years (21 meals × 0.6 meal of man), equivalent to	13
Total number of meals equivalent to	87

Equivalent to one man twenty-nine days.

DIETARY STUDY NO. 23A.

This family consisted of two men and two women. They owned their own house of five rooms. During the course of the study they spent 8 cents for tea and 8 cents for coffee in addition to the food materials purchased.

The study continued one day. The number of meals taken was as follows:

	Meals.
Two men	6
Two women (6 meals × 0.8 meal of man), equivalent to	5
Total number of meals equivalent to	11

Equivalent to one man four days.

DIETARY STUDY NO. 24A.

In this family the man was a German, but the woman was American born. There were also three children, aged 10, 6, and 4 years, respectively. The children were well, with bright color and good complexions, but very dirty and untidy. The income of the family was variable, from $5 to $10 per week. They paid $5 a month rent for four rooms. During the course of the study they spent 24 cents for tea and 16 cents for coffee in addition to that for the food materials purchased.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 10 years (21 meals × 0.6 meal of man), equivalent to	13
Child, 6 years (21 meals × 0.5 meal of man), equivalent to	11
Child, 4 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	70

Equivalent to one man twenty-three days.

TABLE 11.—*Weights and cost of food and nutrients in dietary studies of German families.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 19a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Shoulder, 9.5 pounds, 69 cents (19). Mutton, 8 pounds, 73 cents (51). Veal, 3 pounds, 25 cents (37)	1.67	6.2	53	39	....	559
Pork: Scrapple, 1.5 pounds, 11 cents (67); lard, 5 pounds, 6 cents (62)	.17	.6	1	13	3	132
Eggs, 1 pound, 24 cents (105)	.24	.9	2	2	....	26
Butter, 1.25 pounds, 39 cents (106)	.39	1.4	....	18	....	160
Total animal food	2.47	9.1	56	72	3	877
VEGETABLE FOOD.						
Cereals: Bread, 22 pounds, $1.06 (147); pies, 4 pounds, 20 cents (158); flour, 9 pounds, 43 cents (122)	1.69	6.3	53	13	338	1,680
Sugar, 2 pounds, 12 cents (163)	.12	.4	....	....	34	136
Vegetables: Potatoes, 21 pounds, 49 cents (196); sauerkraut, 1 pound, 10 cents (204); cabbage, 1.56 pounds, 10 cents (181)	.69	2.6	9	....	67	304
Fruit, oranges, 0.6 pound, 6 cents (238)	.06	.2	....	....	....	....
Total animal food	2.56	9.5	62	13	439	2,120
Total food	5.03	18.6	118	85	442	2,997
Dietary study No. 20.						
ANIMAL FOOD.						
Beef: Shoulder, 2.5 pounds, 24 cents (19); liver, 2 pounds, 12 cents (8)	.36	1.5	15	5	1	109
Pork: Scrapple, 2 pound, 16 cents (67); ham, 7 pounds, 42 cents (62); lard, 1 pound, 10 cents (62)	.68	2.8	20	70	4	719
Fish, herring, smoked, 0.9 pound, 15 cents (88)	.15	.6	3	2	....	30
Butter, 0.25 pound, 9 cents (106)	.09	.4	....	4	....	36
Milk, 2.6 pounds, 14 cents (114)	.14	.6	2	2	3	38
Total animal food	1.42	5.9	40	83	8	932
VEGETABLE FOOD.						
Cereals, bread, 7.9 pounds, 38 cents (147)	.38	1.6	14	2	79	390
Sugar, 3 pounds, 18 cents (163); molasses, 1.5 pounds, 8 cents (165)	.26	1.1	1	....	76	308
Vegetables: Potatoes, 7 pounds, 14 cents (196); canned tomatoes, 2 pounds, 11 cents (209); cabbage, 6.2 pounds, 18 cents (181)	.43	1.8	5	....	32	148
Fruit, oranges, 0.3 pound, 8 cents (238)	.08	.3	....	....	....	....
Total vegetable food	1.15	4.8	20	2	187	846
Total food	2.57	10.2	60	85	195	1,778
Dietary study No. 24a.						
ANIMAL FOOD.						
Beef: Shoulder, 7 pounds, 71 cents (19); liver, 2.5 pounds, 17 cents (8)	.88	3.8	33	13	1	252
Pork, lard, 1.5 pounds, 23 cents (62)	.23	1.0	....	30	....	267
Milk, 8.4 pounds, 32 cents (114)	.32	1.4	5	7	8	114
Total animal food	1.43	6.2	38	50	9	633
VEGETABLE FOOD.						
Cereals: Bread, 24.8 pounds, 88 cents (147); buns, 2.1 pounds, 18 cents (148); flour, 24 pounds, 72 cents (122); rice, 0.5 pound, 4 cents (133)	1.82	7.9	102	14	646	3,117
Sugar, 10 pounds, 56 cents (163)	.56	2.4	....	....	197	788
Vegetables: Potatoes, 21 pounds, 45 cents (196); canned tomatoes, 1.8 pounds, 12 cents (209)	.57	2.5	9	1	78	357
Fruits, jelly, 3.5 pounds, 28 cents (235)	.28	1.2	1	....	41	168
Total vegetable food	3.23	14.0	112	15	962	4,430
Total food	4.66	20.2	150	65	971	5,063

TABLE 11.—*Weights and cost of food and nutrients in dietary studies of German families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 21a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Suet, 3 pounds, 15 cents (35); shoulder, 8.75 pounds, 87 cents (19); shin, 2 pounds, 16 cents (17); round, 1.25 pounds, 18 cents (28)	1.36	4.3	30	48	1	551
Pork: Ham, 5 pounds, 50 cents (60); sausage, 3 pounds, 47 cents (66); steak, 1.5 pounds, 20 cents (69)	1.17	3.6	18	49	....	508
Eggs, 1.5 pounds, 22 cents (105)	.22	.7	3	2	....	30
Butter, 1 pound, 36 cents (106)	.36	1.1	....	12	....	107
Milk, skim, 16 pounds, 32 cents (115)	.32	1.0	8	1	12	89
Total animal food	3.43	10.7	59	112	13	1,285
VEGETABLE FOOD.						
Cereals: Corn meal, 12 pounds, 42 cents (119); flour, 1.5 pounds, 11 cents (122); bread, 25 pounds, 76 cents (147); cakes, 3.75 pounds, 40 cents (151)	1.69	5.3	55	16	371	1,846
Sugar, 1 pound, 6 cents (163)	.06	.2	....	....	14	56
Vegetables, potatoes, 14 pounds, 35 cents (196)	.35	1.1	4	....	37	164
Total vegetable food	2.10	6.6	59	16	422	2,066
Total food	5.53	17.3	118	128	435	3,351
Dietary study No. 22a.						
ANIMAL FOOD.						
Beef: Shoulder, 7 pounds, 66 cents (19); round, 5 pounds, 98 cents (28)	1.64	6.1	36	18	....	304
Pork: Sausage, 3.25 pounds, 45 cents (66); pork chops, 2 pounds, 28 cents (58); lard, 2 pounds, 31 cents (62)	1.04	3.8	12	66	1	639
Fish: Whitefish, 8 pounds, 56 cents (103)	.56	2.1	11	4	....	92
Eggs, 1.75 pounds, 51 cents (105)	.51	1.9	4	3	....	43
Butter, 2.25 pounds, 90 cents (106)	.90	3.3	....	32	....	285
Total animal food	4.65	17.2	66	123	1	1,363
VEGETABLE FOOD.						
Cereals: Bread, 18 pounds, 79 cents (147); buckwheat, 2 pounds, 10 cents (118); flour, 20 pounds, 81 cents (122); ginger cakes, 1.5 pounds, 12 cents (157)	1.82	6.7	70	10	458	2,201
Sugars, etc.: Sugar, 7 pounds, 42 cents (163); molasses, 1.5 pounds, 8 cents (165)	.50	1.9	....	....	135	540
Vegetables: Potatoes, 24.5 pounds, 49 cents (196); onions, 1.6 pounds, 2 cents (189); cabbage, 1.4 pounds, 4 cents (181); canned tomatoes, 1.8 pounds, 10 cents (209); turnips, 3.75 pounds, 7 cents (212)	.72	2.7	11	1	84	389
Total vegetable food	3.04	11.3	81	11	677	3,130
Total food	7.69	28.5	147	134	678	4,493
Dietary study No. 23a (duration, 1 day).						
ANIMAL FOOD.						
Beef: Shoulder, 1.5 pounds, 15 cents (19); bologna, 1 pound, 13 cents (1)	.28	7.0	49	37	....	525
Fish: Smoked herring, 0.9 pound, 10 cents (88)	.10	2.5	21	9	....	164
Eggs, 0.25 pound, 5 cents (105)	.05	1.3	4	3	....	43
Butter, 0.25 pound, 10 cents (106)	.10	2.5	....	24	....	214
Milk, 4.2 pounds, 16 cents (114)	.16	4.0	16	19	24	329
Total animal food	.69	17.3	90	92	24	1,275

Table 11.—*Weights and cost of food and nutrients in dietary studies of German families*—Continued.

Food consumed during the whole study (7 days).	Cost, nutrients, and fuel value of food per man per day.					
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 23a (duration 1 day)—Cont'd.						
VEGETABLE FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Cereals: Flour, 0.9 pound, 3 cents (122); white bread, 2.25 pounds, 10 cents (147); rye bread, 2.25 pounds, 10 cents (146); buns, 0.7 pound, 5 cents (149)	0.28	7.0	65	11	392	1,926
Sugar, 1 pound, 5 cents (163)	.05	1.3	....	....	114	456
Vegetables: Potatoes, 3.5 pounds, 9 cents (196); dried beans, 1 pound, 4 cents (177)	.13	3.2	34	3	139	719
Total vegetable food	.46	11.5	99	14	645	3,101
Total food	1.15	28.8	189	106	669	4,376

DIETARY STUDY OF AN AMERICAN FAMILY (No. 25a).

This family comprised two healthy women of frugal habits. They occupied three rooms, for which they paid $6 a month. During the period of the study they spent 15 cents for tea in addition to the purchase of food.

The study continued seven days. The number of meals taken was 42, equivalent to 34 meals of a man, or equivalent to 1 man 11 days.

Table 12.—*Weights and cost of food and nutrients in a dietary study of an American family.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 25a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Shoulder, 1.5 pounds, 24 cents (19). Veal, 1 pound, 20 cents (37); liver, 1 pound, 6 cents (8)	0.50	4.5	25	8	1	175
Pork, scrapple, 1 pound, 6 cents (67)	.06	.5	1	8	5	95
Fish, mackerel, 1.75 pounds, 22 cents (91)	.22	2.0	7	3	....	55
Butter, 1 pound, 40 cents (106)	.40	3.6	1	35	....	316
Cheese, cottage, 0.5 pound, 5 cents (110)	.05	.5	4	....	1	20
Milk, 1.06 pounds, 4 cents (114)	.04	.4	2	2	2	34
Total animal food	1.27	11.5	40	56	9	695
VEGETABLE FOOD.						
Cereals: Bread, 7 pounds, 35 cents (147); doughnuts, 1 pound, 10 cents (156); corn meal, 2 pounds, 5 cents (119)	.50	4.5	37	14	237	1,221
Sugar, 3 pounds, 14 cents (163); molasses, 1.5 pounds, 8 cents (165)	.22	2.0	2	....	167	676
Vegetables: Cabbage, 2.76 pounds, 10 cents (181); cabbage, pickled, 1.5 pounds, 10 cents (181)	.20	1.8	2	....	8	40
Fruits: Prunes, 1 pound, 15 cents (247); bananas, 2.5 pounds, 10 cents (218); oranges, 0.75 pound, 10 cents (238); strawberry preserve, 1 pound, 12 cents (251)	.57	5.2	2	1	53	229
Total vegetable food	1.19	13.5	43	15	465	2,166
Total food	2.76	25.0	83	71	474	2,861

DIETARY STUDIES OF IRISH FAMILIES (Nos. 26a–28a).

The details of three dietary studies with Irish families follow:

DIETARY STUDY NO. 26A.

This family consisted of a man, a woman, and four children; aged 9, 7, and 2½ years, and 9 months, respectively. The woman was not strong; the children were well but pale. The income of the family was $15 per week. They paid $10 a month rent for four rooms and a bathroom. During the course of the study they spent $1.12 for tea and coffee, 8 cents for salt and pepper, and 5 cents for pickles.

The study continued 7 days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Two children, 9 and 7 years (42 meals × 0.5 meal of man), equivalent to	21
Child, 2½ years (21 meals × 0.4 meal of man), equivalent to	9
Child, 9 months (21 meals × 0.3 meal of man), equivalent to	6
Total number of meals equivalent to	74

Equivalent to one man twenty-five days.

DIETARY STUDY NO. 27A.

This was a storekeeper's family, comprising a man and a woman. They paid $12 a month rent for three rooms, not including the store, which was on another street. They spent 20 cents for tea in addition to the food materials purchased during the course of the study.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Total number of meals equivalent to	38

Equivalent to one man thirteen days.

DIETARY STUDY NO. 28A.

This family included a man, a woman, and five children, aged respectively 15, 12, 9, and 5 years, and 21 months. They were rather sickly. The man was a painter, out of work at the time of the study. When employed he earned $15 per week. One of the children, a boy, earned $3 per week. They paid $12 a month rent for a house of five rooms, the rent being applied to the purchase of the house. During the course of the study they spent 15 cents for tea, 30 cents for coffee, and 5 cents for yeast in addition to the food materials purchased.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 15 years (21 meals × 0.8 meal of man), equivalent to	17
Child, 12 years (21 meals × 0.7 meal of man), equivalent to	15
Child, 9 years (21 meals × 0.5 meal of man), equivalent to	11
Child, 5 years (21 meals × 0.4 meal of man), equivalent to	8
Child, 21 months (21 meals × 0.3 meal of man), equivalent to	6
Total number of meals equivalent to	95

Equivalent to one man thirty-two days.

TABLE 13.—*Weights and cost of food and nutrients in dietary studies of Irish families.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 26a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Round, 7 pounds, $1.20 (28); shoulder, 5 pounds, 52 cents (19). Mutton, 3 pounds, 36 cents (51). Veal, 1 pound, 20 cents (37)	2.28	9.1	50	29		458
Pork: Sausage, 1 pound, 14 cents (66); chops, 3 pounds, 51 cents (58); ham, 1 pound, 20 cents (60); lard, 1 pound, 16 cents (62)	1.01	4.1	12	45		448
Fish: Mackerel, 1 pound, 18 cents (91); whitefish, 2 pounds, 20 cents (103)	.38	1.5	6	2		42
Milk, 18.9 pounds, 72 cents (114)	.72	2.9	11	14	17	237
Cheese, Neufchatel, 1 pound, 16 cents (112)	.16	.6	3	5		57
Total animal food	4.55	18.2	82	95	17	1,242
VEGETABLE FOOD.						
Cereals: Bread, 32 pounds, $1.60 (147); buckwheat, 2 pounds, 10 cents (118); barley, 1 pound, 3 cents (117); cake, 0.5 pound, 10 cents (150); doughnuts, 1 pound, 10 cents (156)	1.93	7.7	60	13	365	1,816
Sugar, 6 pounds, 36 cents (163)	.36	1.4			109	436
Vegetables: Potatoes, 24.5 pounds, 85 cents (196); canned tomatoes, 7.1 pounds, 44 cents (209); sauerkraut, 2 pounds, 18 cents (204), cabbage, 1.4 pounds, 5 cents (181), onions, 1.6 pounds, 5 cents (189); turnips, 6 25 pounds, 14 cents (212); dried peas, 1 pound, 12 cents (193), corn, canned, 1,3 pounds, 12 cents (184)	1.95	7.8	18	2	113	512
Fruits, prunes, 1 pound, 16 cents (247)	.16	.6			12	48
Total vegetable food	4.40	17.6	78	15	599	2,842
Total food	8.95	35.8	160	110	616	4,084
Dietary study No. 27a.						
ANIMAL FOOD.						
Beef: Corned, 2 pounds, 24 cents (2); stewing, 3 pounds, 22 cents (33); chuck, 3 pounds, 36 cents (11); bologna, 1 pound, 12 cents (1). Mutton, 1.5 pounds, 12 cents (51)	1.06	8.1	57	54		709
Fish, haddock, 3 pounds, 18 cents (84)	.18	1.4	9			36
Eggs, 1.63 pounds, 33 cents (105)	.33	2.5	7	5		73
Butter, 3 pounds, 60 cents (106)	.60	4.6	1	89		796
Milk, 11.5 pounds, 44 cents (114)	.44	3.4	13	16	20	274
Total animal food	2.61	20.0	87	164	20	1,888
VEGETABLE FOOD.						
Cereals: Oatmeal, 3 pounds, 15 cents (130); barley, 0.5 pound, 3 cents (117); flour, 9 pounds, 27 cents (122)	.45	3.4	54	11	318	1,586

TABLE 13.—*Weights and cost of food and nutrients in dietary studies of Irish families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 27a—Continued.						
VEGETABLE FOOD—continued.						
	Dollars.	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Sugars and starches: Sugar, 1.5 pounds, 18 cents (163); cornstarch, 1 pound, 5 cents (172)	0.23	1.8	....	....	84	336
Vegetables: Potatoes, 12.25 pounds, 35 cents (196); cabbage, 1.38 pounds, 5 cents (181); onions, 0.8 pound, 2 cents (189); carrots, 0.34 pound, 1 cent (182); turnips, 1.4 pounds, 3 cents (212); canned tomatoes, 3.5 pounds, 20 cents (209)	.66	5.1	12	1	92	425
Total vegetable food	1.34	10.3	66	12	494	2.347
Total food	3.95	30.3	153	176	514	4,235
Dietary study No. 28a.						
ANIMAL FOOD.						
Beef: Round, 4 pounds, 62 cents (28); shoulder, 2 pounds, 24 cents (19); liver, 1 pound, 8 cents (8); bologna, 2.5 pounds, 30 cents (1). Veal, 2 pounds, 28 cents (37)	1.52	4.8	30	16	....	260
Pork: Rib, 1 pound, 12 cents (54); scrapple, 2 pounds, 18 cents (67); lard, 1.5 pounds, 20 cents (62)	.50	1.6	3	30	3	291
Butter, 3 pounds, $1.10 (106)	1.10	3.4	....	36	....	320
Milk, 9.4 pounds, 36 cents (114)	.36	1.1	4	5	7	89
Cheese, 1 pound, 13 cents (111)	.13	.4	4	5	....	61
Total animal food	3.61	11.3	41	92	10	1,021
VEGETABLE FOOD.						
Cereals: Barley, 0.5 pound, 3 cents (117); flour, 14 pounds, 40 cents (122); cake, 0.9 pound, 10 cents (150); buns, 3.95 pounds, 25 cents (148); bread, 9.5 pounds, 46 cents (147)	1.24	3.9	40	9	266	1,304
Sugars, etc.: Sugar, 9 pounds, 47 cents (163); sirup, 0.75 pound, 5 cents (166)	.52	1.6	....	....	135	540
Vegetables: Canned corn, 1.9 pounds, 22 cents (184); potatoes, 24.5 pounds, 77 cents (196); greens, 3.25 pounds, 11 cents (205)	1.10	3.4	9	1	70	325
Total vegetable food	2.86	8.9	49	10	471	2,169
Total food	6.47	20.2	90	102	481	3,190

SUMMARY AND GENERAL DEDUCTIONS.

The results of the dietary studies in Philadelphia are summarized in the following table:

TABLE 14.—*Summary of results of dietary studies of Philadelphia families.*

Dietary study number.	Families.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
		Cents.	*Grams.*	*Grams.*	*Grams.*	*Calories.*
7a	Colored	9.1	65	69	210	1,715
8a	.....do	26.4	80	121	332	2,726
9a	.....do	26.3	123	164	482	3,880
10a	.....do	17.2	80	69	258	1,967
11a	.....do	26.3	187	182	587	4,716
	Average	21.1	107	121	374	3,001

TABLE 14.—*Summary of results of dietary studies of Philadelphia families*—Cont'd.

Dietary study number.	Families.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
		Cents.	*Grams.*	*Grams.*	*Grams.*	*Calories.*
12a	Italian	22.7	102	130	477	3,473
13a	.....do	35.4	127	103	259	2,462
	Average	29.0	114	116	368	2,968
14a	German Jew	19.1	83	44	488	2,676
17a	.....do	24.2	152	107	522	3,651
18a	.....do	18.9	115	78	615	3,615
15a	Russian Jew	19.9	85	67	258	1,969
16a	Roumanian Jew	21.0	165	50	599	3,502
	Average	20.6	120	69	496	3,086
19a	German	18.6	118	85	442	2,997
20a	.....do	10.2	60	85	195	1,778
21a	.....do	17.3	118	128	435	3,351
22a	.....do	28.5	147	134	678	4,493
23a	.....do	28.8	189	106	669	4,376
24a	German-American	20.2	150	65	971	5,063
	Average	20.6	130	101	565	3,676
25a	American	25.0	83	71	474	2,861
26a	Irish	35.8	160	110	616	4,084
27a	.....do	30.3	153	176	514	4,235
28a	.....do	20.2	90	102	481	3,190
	Average	28.8	135	129	537	3,836
	Average of all 22 studies	22.8	115	102	476	3,308

In several of the studies the cost of the diet per man per day was relatively very high, and in nearly all of them it was higher than was necessary. The average given in the table above, while indicating what these families spent for their food, represents a greater amount than it was necessary to spend in those regions, in the time when these studies were made, to provide a diet in every way as satisfactory as the average obtained in the studies. Thus, 14 of the 22 families included in these studies paid from 20 to 36 cents per man per day for food materials (not including food accessories) which supplied no more nutrients or energy than it was estimated could have been obtained for 15 cents if there had been more intelligence in marketing; and those families who spent less than 20 cents per man per day for food obtained less than they should for the money spent. This is quite apparent upon a study of the results summarized above. For instance, among the 5 colored families 3 of them spent practically the same amount for their food, namely 26.3 cents per man per day in two cases and 26.4 cents in the third. But the quantities of nutrients and energy obtained varied widely. Thus, in study No. 8a the family obtained per man per day but 80 grams of protein and 2,786 calories of energy; the family in study No. 9a spent 0.1 cent per day less, but got 43 grams of protein and 1,154 calories of energy more, while the family in study No. 11a for the same expenditure secured 187 grams of protein and over 4,700 calories of energy. The family in study No. 10a spent 17.2

cents per man per day, and obtained just as much protein as the family in dietary study No. 8a for 26.4 cents, but only about two-thirds as much energy; this deficiency being due to the fact that they expended a smaller proportion of their money upon pork and vegetable foods and thus secured less fat and carbohydrates. The family in dietary study No. 7a were certainly underfed; they spent but 9.1 cents per man per day for food, and obtained for it but 65 grams of protein and a little over 1,700 calories of energy. Their purchases, however, were just about as economical as those in dietary study No. 11a.

The results with the two Italian families studied differed considerably. The family in study No. 12a spent 22.7 cents per man per day, and obtained 102 grams of protein, and nearly 3,500 calories of energy, while the family in study No. 13a spent 35.4 cents and got a little more protein—127 grams—but only about two-thirds as much energy as in No. 12a. These were among the least economical of the families included in these studies.

The group in which there was the most uniformity as regards the quantity of nutrients and energy of the diet, and also with respect to economy of purchase, was that made up of German families. In the average of the 6 families of this group the diet cost 20.6 cents per man per day, and furnished 130 grams of protein and very nearly 3,700 calories of energy. One family in this study was considerably underfed, spending only 10.2 cents per man per day for their food. This was practically just half of the amount spent by the average; but for this expenditure they secured very nearly half of the protein and energy found in the average diet for the group.

Of all the families studied in Philadelphia, the woman in dietary study No. 24a of this group was believed by the investigator to show the most intelligence on the subject of marketing. She had tried all the markets in the vicinity of her home until she had found the most reasonable one, which she then patronized regularly. For 20.2 cents per man per day she secured 150 grams of protein and 5,063 calories of energy, while the family in study No. 22a, to obtain almost as much protein, but somewhat less energy, expended 28.5 cents.

In the average of the results with the five Jewish families the cost of the diet was the same as that for the German families, but the average diet of the Jewish families provided on the average only 120 grams of protein and 3,086 calories of energy. Two of the families, those in the studies Nos. 14a and 15a, were decidedly less economical than the rest of the group, and although they spent a sufficient amount of money they were hardly sufficiently fed when compared with other families and with the average of all of them.

The cost of the diet in the average for the three Irish families was very nearly the same as that for the Italian families, but the quantities of nutrients and energy procured were noticeably larger for the former.

The only native American family included in these studies was that in study No. 25a. They spent 25 cents per man per day, for which they secured 83 grams of protein and 2,861 calories of energy—a diet exactly the same in protein and but very little higher in energy than that in study No. 14a (a German-Jewish family), which cost 6 cents per day less.

Most of the above comparisons of different diets as regards economy have been made between families of the same nationality. Similar facts are observed in comparing the results with families of different nationalities. Thus in dietary study No. 24a with the German-American family the cost of the diet was 20.2 cents per man per day, for which 150 grams of protein and 5,063 calories of energy were secured, while in dietary study No. 28a, with an Irish family, the cost per man per day was exactly the same, but only 90 grams of protein and 3,190 calories of energy were secured. The family of Roumanian Jews in dietary study No. 16a spent 21 cents per man per day, a trifle more than the two families just mentioned, and secured 165 grams of protein and 3,502 calories of energy; that is, little more protein but much less energy than in the family in study No. 24a. Again, the colored family in dietary study No. 10a spent 17.2 cents per man per day and secured but 80 grams of protein and 1,967 calories of energy, while the German family in study No. 21a spent 17.3 cents per man per day and secured 118 grams of protein and 3,351 calories of energy. The two most expensive dietaries in the whole number were that of the Italian family in the study No. 13a and that of the Irish family in study No. 26a. The former spent 35.4 cents per man per day and secured 127 grams of protein and 2,462 calories of energy, while the latter spent 35.8 cents per man per day and secured 160 grams of protein and 4,084 calories of energy.

It is interesting to observe that the family in study No. 13a consisted of two women; so also did those in Nos. 25a and 11a. In all three the cost calculated to the basis per man per day was high, but the economy of the diets purchased varied widely.

So few data regarding the occupations of the different families are available that but little can be said concerning the fitness of the diets. Most of the families were without regular incomes, so it may be inferred that they were not engaged in steady work. The average of the 22 studies summarized above agrees practically with the common standard for a man at light to moderate muscular work; the number of studies in which the diet was fairly near the average, however, was small, the larger part of them being either considerably higher or lower than this. The family in study No. 27a was that of a storekeeper. The diet in this study, furnishing 153 grams of protein and

4,235 calories of energy, would certainly seem to be ample. The family in study No. 22a also kept a store, but it was looked after by the woman during the day, while the man was away at work. In this case also the diet with 147 grams of protein and 4,493 calories of energy would seem to be more than sufficient, unless the man was engaged in hard work. In the notes concerning the family in study No. 18a it was stated that one room of the house was used as a tailor shop. If tailoring was the occupation in this case, the diet, which furnished 115 grams of protein and 3,615 calories of energy, was certainly sufficient. One of the two women who comprised the family in study No. 11a was a washerwoman. If steadily employed she would doubtless require considerably more food than the average woman; but it would hardly be expected that the diet for the two women would need to average 187 grams of protein and 4,716 calories of energy per man per day as found in this study.

Two faults, then, are quite generally evident in these studies. There was a tendency to buy too much where there was sufficient money, and the prices paid for nourishment were considerably higher than was necessary.

One reason for the expensiveness of the diet was found in the way the families lived. Since they had no regular incomes they could not purchase their food materials in quantities, but bought their provisions only on the day they were used and only as much as was needed at the time. Such method of purchasing materials in small quantities is always more expensive than buying in larger amounts.

Furthermore, almost every one of the families in the Philadelphia studies bought groceries and provisions at the small corner stores so common in that city, rather than at the larger markets where the goods could be obtained much cheaper. For instance, the small corner grocery in the vicinity of the settlement charged 5 cents a pound for flour, while the best flour could be had at a larger store a little farther away for 3½ cents, even in small quantities. The only butter for sale at the small store cost 40 cents a pound, while good butter could be purchased at a market two blocks away for 28 or 30 cents. At the same market cuts of meat like neck and shin could be obtained for 3½ and 4 cents a pound which at the smaller store cost 6 cents. Milk in small quantities cost not less than 8 cents a quart.

Not only were the food materials sold at the small store generally higher in price than could be obtained elsewhere, but the majority of them in the poorer quarters of the city were of inferior quality.

One article which had considerable effect upon the cost of the dietaries, because it was used so generally and in such large quantities, was bread. Bakers' bread was used by about half of the families. The so-called pound loaf sold by the bakers weighed usually more than that—on an average about 1⅛ pounds. The loaves were about a third larger than the ordinary pound loaf of homemade bread, but they were excessively raised and dried quickly, and altogether were far from the ideal nutty, firm, nutritious loaf.

In regard to green vegetables the conditions were more favorable. The poorer streets of the city were usually well provided with these in their season and at prices about as reasonable as in the large markets. Many hucksters and farmers brought their vegetables directly to the streets in which these families lived and sold them without the middleman's profit.

To some extent the people in these regions were not responsible for the costliness of their diet. In no case were there any conveniences for the use of ice for keeping food, and in few if any cases was there sufficient money to enable them to buy in very large quantities. But while the costliness of the diet may be accounted for to some extent by lack of space to keep quantities of provisions and lack of money to buy them, a considerable part of it was unnecessary, as was shown by a comparison of the different diets as regards economy, and for people in the circumstances of those of the families studied it was unwarrantable. A little more intelligence in the matter of marketing would have enabled many of the families to provide practically the very same diet at a much smaller cost, or a better diet for the sum expended. This fact has been well illustrated by a comparison of the diet obtained by the woman in study No. 24a with that secured by other families for the same money or more. This woman had found that in the small store near her home food materials cost her very much more than in the market a few blocks farther away. She could get good sugar at 4 cents at the market, or larger store, which would cost her 6 cents at the small store. Meat for which she would have to pay 10 cents at the small store she could get for 6 cents at the market. Accordingly she traded at the market as much as possible.

A little knowledge of the comparative nutritive values of food materials would have enabled a number of the families in these studies to have saved a considerable part of the money spent for food by using different kinds of food materials from those purchased. Some of the families used the higher priced cuts of meat while others obtained more nourishment for the same or less money spent for cheaper cuts. Two of the families used cornmeal and two used rye bread during the weeks when the studies were made. None of the rest used any other meal or flour than the higher priced white flour, although the cheaper grades of flour are by many regarded as equally nutritious and palatable. Dried beans occurred in nine of the dietaries and dried peas in five, but only in small quantities and not as a staple article of food, notwithstanding that these are among the cheapest and most nutritious of foods commonly available. In the more general use of dried peas, beans, cornmeal and the cheaper cuts of meat, these dietaries could have been not only cheapened as to cost, but where there was little to spend, greatly increased in nutritive value.

DETAILS OF THE STUDIES IN CHICAGO.

The dietary studies in Chicago were made in the spring in the vicinity of Hull House among families in the region in which the work of the settlement was carried on.

No difficulty was experienced in securing from the families selected permission to make the studies, as the work of the Hull House was well known to them and appreciated. As was the case in Philadelphia, the families were believed to be typical of those living in the thickly congested regions of our large cities. The families studied in Chicago were superior as regards intelligence, etc., to those studied in Philadelphia. As regards nationality, they comprised native Americans, Americans of German and Irish descent, Scotch, English, Irish and German, American-Irish, English-American, English-Irish, German-American, French-Canadian, Hungarian, and Bohemian. Most of these families were in much better circumstances than those studied in Philadelphia, a large portion of them having good incomes. In nearly all of them the women were members of the Hull House woman's club. The kind help and interest of this association in the investigations rendered success in the undertaking easier.

The attempt was made to secure as accurate data as possible regarding the kinds and cost of food consumed, but in these studies more reliance had to be placed on the housekeepers than was the case in the studies in Philadelphia, since with the number undertaken it was impossible to devote the time to the work which would have been required for personal supervision of every detail. The data of the studies, however, are believed to be quite trustworthy. Altogether 33 studies were made in Chicago, of which the results of 32 are given in the present bulletin. The results of 3 of the studies included, however, namely, Nos. 33a, 51a, and 59a are somewhat doubtful. All the others are believed to be more satisfactory. The details of the studies follow.

DIETARY STUDIES OF AMERICAN FAMILIES (Nos. 29a–35a).

Three studies were made with American families. Of these, 7 (Nos. 29a–35a) were with native Americans, 5 (Nos. 36a–40a) were with Americans of German descent, and 1 (No. 41a) with Americans of Irish descent.

DIETARY STUDY NO. 29A.

The family in this study consisted of two men and two women. The income of the family was $150 a month. They paid $16 a month rent for six rooms. The health of the family was not the best. The woman had neuralgia: the daughter had had typhoid fever. The son was not hungry in the morning but was at about 11 o'clock, although he had not time to get anything to eat then. During the course of the study the family spent 5 cents for watercress, 38 cents for coffee, and 35 cents for tea, in addition to the food materials purchased.

The study continued seven days. One man took his lunch daily away from home. The number of meals taken at home was therefore as follows:

	Meals.
Two men	28
Two women (42 meals × 0.8 meal of man) equivalent to	34
Total number of meals equivalent to	62

Equivalent to one man twenty-one days.

DIETARY STUDY NO. 30A.

This family consisted of two men, two women, and two children, aged 14 and 3 years, respectively. The head of the family was a carpenter. They were all in good health. The children drank coffee for breakfast and tea for supper. The woman was very neat and intelligent and patronized the large markets. They paid $14 a month rent for seven rooms. During the study she spent 5 cents for ginger, 10 cents for catsup, 25 cents for tea, and 35 cents for coffee in addition to the food materials purchased. The fuel used during the time of the study cost about 55 cents.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Two men	39
Two women (42 meals ×0.8 meal of man), equivalent to	34
One child, 14 years (21 meals ×0.7 meal of man), equivalent to	15
One child, 3 years (21 meals ×0.4 meal of man), equivalent to	8
Total number of meals equivalent to	96

Equivalent to one man thirty-two days.

DIETARY STUDY NO. 31A.

This family consisted of one man, two woman, and a child 8 years of age. They were all vigorous and in good health. The child was allowed coffee or tea, one cup, three times a day. The income of the family was $83 a month. They paid $25 a month rent for eight rooms. The woman did not buy her provisions at the large markets. She spent 5 cents for tea, 15 cents for coffee, and 2 cents for soup greens in addition to the food materials purchased. The fuel during the week cost about $1.75.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Two women (42 meals × 0.8 meal of man), equivalent to	34
Child, 8 years (21 meals × 0.5 meal of man), equivalent to	10
Total number of meals equivalent to	65

Equivalent to one man twenty-two days.

DIETARY STUDY NO. 32A.

This family consisted of two rather elderly people, a man and a woman, who kept a little news and variety shop. They were both in good health. Their income was $18 to $20 a week and they paid $20 a month rent for five rooms. The fuel during the week cost them about 80 cents. In addition to the food materials purchased they spent 4 cents for watercress, 15 cents for tea, and 18 cents for coffee.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Total number of meals equivalent to	38

Equivalent to one man thirteen days.

DIETARY STUDY NO. 33A.

The family consisted of a man, a woman, and three children, aged respectively 8, 5, and 3 years. The income of the family was $16 a week. They received $5 a month for board for one member of the family. They paid $15 a month rent for four rooms. The children had fine complexions and appeared to be very well. They were fed largely on bread, milk, and potatoes, but were also allowed to drink tea and coffee. The meat used was bought largely for the benefit of the man. The figures for the study are somewhat doubtful, but they were taken just as given by the woman, who was not very intelligent.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 8 years (21 meals × 0.5 meal of man), equivalent to	11
Two children, 5 and 3 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	57

Equivalent to one man nineteen days.

DIETARY STUDY NO. 34A.

The family in this study consisted of four men, two women, and two children, one 9 years old and the other 10 months old; the latter not being included in the study. The income of the family was $30 a week. Boarders paid $7 a week. The family paid $20 a month rent for six rooms and $7 for a barn. The children drank tea and coffee, except on Sunday when they drank milk and beer. They had apparently very good health. In addition to the food materials purchased 60 cents was spent for coffee and 40 cents for tea.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Four men	77
Two women (42 meals × 0.8 meal of man), equivalent to	34
Child, 9 years (21 meals × 0.5 meal of man), equivalent to	11
Total number of meals equivalent to	122

Equivalent to one man forty-one days.

DIETARY STUDY NO. 35A.

This family consisted of three men, weighing respectively 154, 137, and 135 pounds; two women, weighing 143 and 109 pounds, respectively, and two children, one 13 years old weighing 75 pounds and one 7 years old weighing 38 pounds. One of the men was sick with typhoid fever and consumed only eggnogg, so he was not included in the study. The rest of the family appeared to be in fair health. The children drank coffee once a day and tea twice. The income of the family was $15 a week. They paid $10 a month rent for four rooms. In addition to food materials purchased they spent 20 cents for tea and 60 cents for coffee. Fuel cost them 50 cents per week.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Two men	42
Two women (42 meals × 0.8 meal of man), equivalent to	34
Child, 13 years (21 meals × 0.7 meal of man), equivalent to	15
Child, 7 years (21 meals × 0.5 meal of man), equivalent to	11
Total number of meals equivalent to	102

Equivalent to one man thirty-four days.

DIETARY STUDY NO. 36A.

This family consisted of two men, two women, and one child 10 years of age. They were clean and intelligent and in good health. The child drank milk mostly. The income of the family was $25 a week. They paid $11 a month rent for four rooms. Forty-five cents was spent during the week for coffee and tea and 35 cents for fuel.

The study continued seven days. There were adult visitors present at seven meals, therefore the number of meals taken was as follows:

	Meals.
Two men	42
Two women (42 meals × 0.8 meal of man), equivalent to	34
Child, 10 years (21 meals × 0.6 meal of man), equivalent to	13
Visitors	7
Total number of meals equivalent to	96

Equivalent to one man thirty-two days.

DIETARY STUDY NO. 37A.

The family in this study consisted of two men, a woman, and five children aged respectively 15, 14, 7, 5, and 3 years. Their income was $97 a month. They paid $9 a month rent for four rooms. During the week they spent 4 cents for pickles, 5 cents for horseradish, 37 cents for coffee, 12 cents for tea, 5 cents for chicory, and 50 cents for fuel.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Two men	42
Woman (21 meals × 0.8 meal of man), equivalent to	17
Two children, 15 and 14 years (42 meals × 0.7 meal of man), equivalent to	29
Child, 7 years (21 meals × 0.5 meal of man), equivalent to	11
Two children, 5 and 3 years of age (42 meals × 04. meal of man), equivalent to	17
Total number of meals equivalent to	116

Equivalent to one man thirty-nine days.

DIETARY STUDY NO. 38A.

The family in this study consisted of three men, two women, and one child 10 years old; all in very good health. The income of the family was $50 a week. They lived in their own house of seven rooms, which would rent for about $20 a month. During the week $1.05 was spent for tea and coffee and 26 cents for pickles, salt, and catsup, besides the food materials purchased.

The study continued seven days. One of the men took his suppers away from home. The number of meals taken was therefore as follows:

	Meals.
Three men	56
Two women (42 meals × 0.8 meal of man), equivalent to	34
Child, 10 years old (21 meals × 0.6 meal of man), equivalent to	13
Total number of meals equivalent to	103

Equivalent to one man thirty-four days.

DIETARY STUDY NO. 39A.

The family in this study consisted of three men, two women, and six children, aged, respectively, 13, 11, 8, 5, 3 years, and 8 months. The latter was not included in the study. The children were pale and did not appear to be very well. All but the baby drank tea, and thought they could not eat a meal without it. The income of the family was $80 a month. They owned a house of eighteen rooms, of which they used nine rooms and rented nine rooms. Their own rent would cost them about $25 a month. The amount spent for food accessories was not stated, except 4 cents for vinegar and 2 cents for yeast.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Three men	63
Two women (42 meals × 0.8 meal of man), equivalent to	34
Child, 13 years (21 meals × 0.7 meal of man), equivalent to	15
Child, 11 years (21 meals × 0.6 meal of man), equivalent to	13
Child, 8 years (21 meals × 0.5 meal of man), equivalent to	11
Two children, 5 and 3 years (42 meals × 0.4 meal of man), equivalent to	17
Total number of meals equivalent to	153

Equivalent to one man fifty-one days.

DIETARY STUDY NO. 40A.

This family consisted of a man, a woman, and five children, aged, respectively, 15, 12, 10, and 2½ years, and 7 months. The baby was not considered in the study. The children drank tea and coffee. They appeared to be in fair health. The income of the family was $9 a week. They lived in their own house of five rooms. During the study they spent 55 cents for coffee and tea, 5 cents for salt, 9 cents for pickles, and 5 cents for mustard.

The study continued seven days. The man got his lunch away from home; hence the number of meals taken was as follows:

	Meals.
Man	14
Woman (21 meals × 0.8 meal of man), equivalent to	17
Two children, 15 and 12 years (42 meals × 0.7 meal of man), equivalent to	29
Child, 10 years (21 meals × 0.6 meal of man), equivalent to	13
Child, 2½ years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	81

Equivalent to one man twenty-seven days.

DIETARY STUDY NO. 41A.

This was an American family of Irish descent, consisting of a man, a woman, and four children, aged, respectively, 13, 10, and 4 years, and 16 months. The health of the family was not good. The woman suffered from rheumatism. Among the children there had been cases of pneumonia, inflammation of the bowels, and measles during the winter preceding the study. The children drank milk, and one of them beer for her health. The income of the family was $35 a month. They paid $12 a month rent for five rooms. They spent 50 cents for tea during the course of the study.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	19
Woman (19 meals × 0.8 meal of man), equivalent to	15
Child, 13 years (19 meals × 0.7 meal of man), equivalent to	13
Child, 10 years (19 meals × 0.6 meal of man), equivalent to	11
Child, 4 years (19 meals × 0.4 meal of man), equivalent to	7
Child, 16 months (19 meals × 0.3 meal of man), equivalent to	5
Total number of meals equivalent to	70

Equivalent to one man twenty-three days.

TABLE 15.—*Weights and cost of food and nutrients in dietary studies of American families.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 29a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Sirloin steak, 5.71 pounds, 71 cents (32). Mutton chops, 3 pounds, 45 cents (46)	1.16	5.5	29	40	....	472
Pork: Spare rib, 4.5 pounds, 30 cents (58)	.30	1.4	13	24	....	266
Fish: Whitefish, 1.5 pounds, 15 cents (103)	.15	.7	3	1	....	21
Eggs, 3 pounds, 32 cents (105)	.32	1.5	8	6	....	85
Cheese, 0.56 pound, 8 cents (111)	.08	.4	3	4	....	48
Milk, 2.09 pounds, 5 cents (114)	.05	.3	2	2	2	34
Total animal food	2.06	9.8	58	77	2	926
VEGETABLE FOOD.						
Cereals: Flour, 16.33 pounds, 55 cents (122)	.55	2.6	41	8	265	1,251
Sugar, 5 pounds, 30 cents (163)	.30	1.4	....	....	108	432
Vegetables: Asparagus, 1.13 pounds, 13 cents (174); cabbage, 1.25 pounds, 7 cents (181); lettuce, 0.63 pound, 12 cents (187); onions (green), 0.56 pound, 25 cents (190); potatoes, 14 pounds, 25 cents (196); spinach, 3.19 pounds, 26 cents (206); tomatoes (canned), 5.34 pounds, 45 cents (209)	1.53	7.3	9	1	54	261
Fruits: Oranges, 0.80 pound, 5 cents (238); strawberries, 1.31 pounds, 26 cents (250)	.31	1.5	....	....	4	16
Total vegetable food	2.69	12.8	50	4	431	1,960
Total food	4.75	22.6	108	81	433	2,886
Dietary study No. 30a.						
ANIMAL FOOD.						
Beef: Bologna, 0.5 pound, 5 cents (1); shin, 2 pounds, 10 cents (17); neck, 2 pounds, 10 cents (9); porterhouse steak, 2 pounds, 24 cents (27); round steak, 1.5 pounds, 15 cents (28); roast rib, 5 pounds, 50 cents (14). Veal cutlet, 1.5 pounds, 20 cents (44). Mutton chops, 1 pound, 13 cents (46)	1.47	4.6	36	31	....	420
Pork: Ham, 1.5 pounds, 30 cents (60); lard, 1 pound, 13 cents (62)	.43	1.3	3	21	....	199
Butter, 4 pounds, $1.28 (106)	1.28	4.0	1	48	....	431
Eggs, 4.5 pounds, 48 cents (105)	.48	1.5	8	6	....	85
Milk, 14.65 pounds, 42 cents (114)	.42	1.3	7	8	10	139
Cream, 1.35 pounds, 12 cents (113)	.12	.4	....	3	1	31
Cheese, 1 pound, 16 cents (111)	.16	.5	4	5	....	61
Total animal food	4.36	13.6	59	122	11	1,366

TABLE 15.—*Weights and cost of food and nutrients in dietary studies of American families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 30a—Continued.						
VEGETABLE FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Cereals: Apple pie, 1 pound, 10 cents (158); bread, 14 pounds, 70 cents (147); buns, 1.25 pounds, 12 cents (148); cakes (ginger), 0.5 pound, 5 cents (157); flour, 8.17 pounds, 20 cents (122)	1.17	3.7	34	7	214	1,054
Sugars: Chocolate, 0.25 pound, 7 cents (167); sirup, 1.5 pounds, 10 cents (1.66); sugar, 10 pounds, 58 cents (163)	.75	2.3	....	2	158	650
Vegetables: Asparagus, 1.69 pounds, 15 cents (174); cabbage, 2.5 pounds, 14 cents (181); corn (canned), 1.31 pounds, 12 cents (184); cucumbers, 2 pounds, 10 cents (186); onions (dry), 1.25 pounds, 6 cents (189); onions (green), 0.19 pound, 10 cents (190); peas (green), 2.72 pounds, 15 cents (194); potatoes, 28 pounds, 55 cents (196); rhubarb, 2 pounds, 5 cents (201); tomatoes (canned), 1.78 pounds, 10 cents (209)	1.52	4.7	11	1	72	341
Fruits: Apples, 4.5 pounds, 15 cents (214); bananas, 3 pounds, 15 cents (218); raisins, 2 pounds, 10 cents (248); strawberries, 1.31 pounds, 23 cents (250)	.63	2.0	1	1	34	149
Total vegetable food	4.07	12.7	46	11	478	2,194
Total food	8.43	26.3	105	133	489	3,560
Dietary study No. 31a.						
ANIMAL FOOD.						
Beef: Shoulder, 1.25 pounds, 12 cents (19); sirloin, 1.25 pounds, 15 cents (32); soup bone, 2 pounds, 5 cents (17). Veal: Loin, 1.5 pounds, 18 cents (41); rib, 3 pounds, 30 cents (43)	.80	3.6	29	15	....	250
Pork: Salt pork, 3 pounds, 36 cents (64); sausage, 1 pound, 10 cents (66); tenderloin, 1 pound, 15 cents (71)	.61	2.8	8	65	....	610
Fish: Cod (salt), 1 pound, 10 cents (80)	.10	.5	3	....	....	12
Butter, 1 pound, 33 cents (106)	.33	1.5	....	18	....	160
Butterine, 1 pound, 16 cents (107)	.16	.7	....	17	....	151
Eggs, 4.5 pounds, 48 cents (105)	.48	2.2	12	9	....	128
Milk, 15.71 pounds, 45 cents (114)	.45	2.1	11	13	16	224
Cheese, 0.75 pound, 12 cents (111)	.12	.5	4	5	1	65
Total animal food	3.05	13.9	67	142	17	1,600
VEGETABLE FOOD.						
Cereals: Cake, 1 pound, 10 cents (150); flour, 4 pounds, 16 cents (122); rolls, 1 pound, 6 cents (159)	.32	1.5	13	4	87	436
Sugar, 2 pounds, 12 cents (163)	.12	.5	....	....	41	164
Vegetables: Beans (dry), 1.96 pounds, 8 cents (177); onions (green), 0.75 pound, 20 cents (190); peas (green), 1.36 pounds, 10 cents (194); potatoes, 10.5 pounds, 27 cents (196)	.65	2.9	14	1	59	301
Fruits: Jelly (currant), 2 pounds, 10 cents (228); lemons, 0.88 pound, 5 cents (236)	.15	.7	....	....	28	112
Total vegetable food	1.24	5.6	27	5	215	1,013
Total food	4.29	19.5	94	147	232	2,613
Dietary study No. 32a.						
ANIMAL FOOD.						
Beef: Sausage, 1 pound, 12 cents (16); shoulder, 2.5 pounds, 20 cents (19); sirloin, 1 pound, 14 cents (32). Mutton chops, 1.5 pounds, 12 cents (46)	.58	4.5	33	36	....	452
Fish: Salmon (canned), 1 pound, 18 cents (96)	.18	1.4	6	3	....	51
Butter, 1 pound, 35 cents (106)	.35	2.7	....	30	....	267

TABLE 15.—*Weights and cost of food and nutrients in dietary studies of American families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 32a—Continued.						
ANIMAL FOOD—continued.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Cheese, 1 pound, 15 cents (111)	0.15	1.2	10	12	1	151
Cream, 4.5 pounds, 42 cents (113)	.42	3.2	4	29	7	302
Eggs, 3.2 pounds, 24 cents (105)	.24	1.8	15	10	...	149
Total animal food	1.92	14.8	68	120	8	1,372
VEGETABLE FOOD.						
Cereals: Apple pie, 1 pound, 12 cents (158); bread, 4 pounds, 20 cents (147); buckwheat, 2 pounds, 10 cents (118); doughnuts, 0.56 pound, 6 cents (156); graham flour, 2 pounds, 10 cents (124); rice, 1 pound, 10 cents (133); whole wheat flour, 2 pounds, 9 cents (123)	.77	5.9	41	13	282	1,408
Sugar, 2.5 pounds, 13 cents (163)	.13	1.0	...	...	87	348
Vegetables: Beans (string), 0.68 pound, 8 cents (178); onions, 2 pounds, 16 cents (189); parsnips, 1.25 pounds, 5 cents (191); potatoes, 7 pounds, 13 cents (196); peas (green), 1.36 pounds, 16 cents (194)	.58	4.5	9	1	53	257
Fruits: Apples, 4.5 pounds, 18 cents (214); oranges, 1.58 pounds, 10 cents (238); strawberries, 2.6 pounds, 42 cents (250)	.70	5.4	1	1	28	125
Total vegetable food	2.18	16.8	51	15	450	2,138
Total food	4.10	31.6	119	135	458	3,510
Dietary study No. 33a.						
ANIMAL FOOD.						
Beef: Rump steak, 0.83 pound, 10 cents (30); sirloin steak, 1.5 pounds, 25 cents (32). Veal chops, 2.75 pounds, 35 cents (41)	.70	3.7	20	15	...	214
Pork: Ham, 0.80 pound, 20 cents (60); lard, 0.5 pound, 7 cents (62); salt pork, 0.62 pound, 5 cents (64)	.32	1.7	3	30	...	279
Fish: Salt cod, 0.5 pound, 5 cents (80)	.05	.3	2	...	...	8
Butter, 5 pounds, $1.25 (106)	1.25	6.5	1	101	...	903
Eggs, 3 pounds, 32 cents (105)	.32	1.7	9	7	...	98
Cream, 7.88 pounds, 35 cents (113)	.35	1.8	5	35	9	368
Milk, 21.99 pounds, 63 cents (114)	.63	3.3	17	21	26	359
Cheese, 0.33 pound, 5 cents (111)	.05	.3	2	3	...	35
Total animal food	3.67	19.3	59	212	35	2,264
VEGETABLE FOOD.						
Cereals: Buns, 5.75 pounds, 44 cents (148); crackers, 0.5 pound, 5 cents (153); flour, 16.66 pounds, 38 cents (122)	.87	4.6	55	14	386	1,889
Sugars, etc.: Chocolate, 1 pound, 20 cents (167); sugar, 9 pounds, 50 cents (162)	.70	3.7	3	12	222	1,007
Vegetables: Beans (string), 0.66 pound, 8 cents (178); peas (green), 0.68 pound, 10 cents (194); potatoes, 24.25 pounds, 63 cents (196)	.81	4.3	11	1	88	405
Fruits: Apple butter, 0.5 pound, 5 cents (215); apricots, 1 pound, 20 cents (217); pineapples, 1.96 pounds, 5 cents (243)	.30	1.5	2	...	25	108
Total vegetable food	2.68	14.1	71	27	721	3,409
Total food	6.35	33.4	130	239	756	5,673
Dietary study No. 34a.						
ANIMAL FOOD.						
Beef: Rump steak, 4 pounds, 40 cents (30); sirloin steak, 2 pounds, 28 cents (32); soup bone, 4.28 pounds, 30 cents (17). Veal: Breast, 5.43 pounds, 38 cents (35); cutlets, 2.5 pounds, 36 cents (44). Mutton: Chops, 3 pounds, 24 cents (46); breast, 5 pounds, 25 cents (45)	2.21	5.4	45	42	...	554

TABLE 15.—*Weights and cost of food and nutrients in dietary studies of American families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 34a—Continued.						
ANIMAL FOOD—continued.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Pork: Ham, 1.5 pounds, 30 cents (60); ham (boiled), 0.6 pound, 15 cents (61); lard, 1 pound, 13 cents (62); pork, 15.25 pounds, $1.81 (58); sausage, 1.5 pounds, 15 cents (66)	2.54	6.2	28	69	....	726
Fish: Trout (lake), 4 pounds, 38 cents (89); whitefish (smoked), 2 pounds, 25 cents (104)	.63	1.5	8	5	....	77
Butterine, 5 pounds, 90 cents (107)	.90	2.2	1	46	....	413
Eggs, 3.75 pounds, 41 cents (105)	.41	1.0	5	4	....	56
Milk, 29.32 pounds, 84 cents (114)	.84	2.1	11	13	16	224
Total animal food	7.53	18.4	98	179	16	2,050
VEGETABLE FOOD.						
Cereals: Apple pie, 1 pound, 10 cents (158); bread (rye), 11 pounds, 45 cents (146); cake, 1.5 pounds, 30 cents (150); flour, 12 pounds, 42 cents (122)	1.27	3.1	27	11	180	926
Sugar, 6 pounds, 36 cents (163)	.36	.8	....	....	66	264
Vegetables: Cucumbers, 12 pounds, 30 cents (186); lettuce, 1.32 pounds, 15 cents (187); onions, 2.5 pounds, 10 cents (189); peas, 5.44 pounds, 25 cents (194); potatoes, 35 pounds, 84 cents (196); radishes, 2.63 pounds, 40 cents (200); spinach, 3.19 pounds, 10 cents (206); tomatoes (canned), 1.78 pounds, 12 cents (209)	2.26	5.5	12	1	72	345
Fruits: Apples, 9 pounds, 36 cents (214); strawberries, 1.3 pounds, 25 cents (250)	.61	1.5	....	....	12	48
Beer, 8 pounds, 40 cents (259)	.40	1.0	1	....	10	44
Total vegetable food	4.90	11.9	40	12	340	1,627
Total food	12.43	30.3	138	191	356	3,677
Dietary study No. 35a.						
ANIMAL FOOD.						
Beef: Shoulder, 3 pounds, 15 cents (19); neck, 2 pounds, 20 cents (9); rump, 5.29 pounds, 43 cents (15); calves' heart, 1.5 pounds, 5 cents (38). Mutton, neck, 3.5 pounds, 15 cents (50)	.98	2.9	30	30	....	387
Pork: Bacon, 0.63 pound, 10 cents (50); fresh loin, 3 pounds, 40 cents (58); ham (boiled), 1 pound, 20 cents (61); salt pork, 1.75 pounds, 24 cents (64); sausage, 1 pound, 12 cents (66)	1.06	3.1	11	44	....	436
Fish: Herring (fresh), 4.17 pounds, 25 cents (87); sardines, 0.28 pound, 6 cents (99); smoked halibut, 0.58 pound, 7 cents (102)	.38	1.1	9	4	....	72
Butter, 1 pound, 30 cents (106)	.30	.9	....	12	....	107
Butterine, 2 pounds, 36 cents (107)	.36	1.1	....	22	....	196
Eggs, 6.75 pounds, 75 cents (105)	.75	2.2	12	8	....	119
Milk, 15.71 pounds, 45 cents (114)	.45	1.3	7	8	10	139
Total animal food	4.28	12.6	69	128	10	1,456
VEGETABLE FOOD.						
Cereals: Bread, 7 pounds, 35 cents (147); flour, 24 pounds, 55 cents (122)	.90	2.6	45	4	290	1,376
Sugar, 6 pounds, 36 cents (163)	.36	1.1	....	....	80	320
Vegetables: Beans (string), 0.66 pound, 10 cents (178); onions (dry), 3.75 pounds, 13 cents (189); onions (green), 0.19 pound, 5 cents (190); potatoes, 28 pounds, 55 cents (196); spinach, 3.19 pounds, 10 cents (206)	.93	2.7	9	1	61	289
Total vegetable food	2.19	6.4	54	5	431	1,985
Total food	6.47	19.0	123	133	441	3,441

TABLE 15.—*Weights and cost of food and nutrients in dietary studies of American families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 36a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Round steak, 6 pounds, 80 cents (28); sirloin steak, 4.75 pounds, 73 cents (32). Veal chuck, 4 pounds, 40 cents (37). Mutton loin, 3 pounds, 30 cents (46)	2.23	7.0	42	35	....	480
Pork: Lard, 2 pounds, 28 cents (62); tenderloin, 2 pounds, 30 cents (71)	.58	1.8	5	32	....	305
Fish: Perch, 3 pounds, 25 cents (94)	.25	.8	3	1	....	21
Butter, 3.5 pounds, 95 cents (106)	.95	3.0	1	42	....	378
Eggs, 6 pounds, 64 cents (105)	.64	2.0	11	8	....	115
Milk, 28.27 pounds, 81 cents (114)	.81	2.5	13	16	20	274
Cream, 2.25 pounds, 20 cents (113)	.20	.6	1	6	1	61
Cheese, 1.5 pounds, 24 cents (111)	.24	.8	6	7	1	90
Total animal food	5.90	18.5	82	147	22	1,724
VEGETABLE FOOD.						
Cereals: Cake, 1 pound, 30 cents (150); flour, 14 pounds, 43 cents (122)	.73	2.3	24	3	158	755
Sugar, 4 pounds, 22 cents (163)	.22	.7	....	....	57	228
Vegetables: Asparagus, 1.13 pounds, 10 cents, (174); butter beans, 1.31 pounds, 15 cents (175); cabbage, 1.23 pounds, 10 cents (181); cucumbers, 3 pounds, 15 cents (186); lettuce, 0.88 pound, 11 cents (187); onions (dry), 2.5 pounds, 6 cents (189); peas (green), 2.75 pounds, 10 cents (194); potatoes, 21 pounds, 43 cents (196); radishes, 0.65 pound, 5 cents, (200); rhubarb, 0.75 pound, 5 cents (201); spinach, 3.19 pounds, 20 cents (206); turnips, 4 pounds, 6 cents (212)	1.56	4.9	11	1	61	297
Fruits: Apples, 4.5 pounds, 15 cents (214); bananas, 3 pounds, 10 cents (218); cherries (canned), 2.25 pounds, 20 cents (221); oranges, 4.75 pounds, 20 cents (238); peaches (canned), 2.25 pounds, 23 cents (239); pineapples, 1.96 pounds, 10 cents (243); prunes, 1 pound, 15 cents (247)	1.13	3.5	2	1	42	185
Total vegetable food	3.64	11.4	37	5	318	1,465
Total food	9.54	29.9	119	152	340	3,189
Dietary study No. 37a.						
ANIMAL FOOD.						
Beef: Corned beef, 7 pounds, 50 cents (2); shank (fore), 4 pounds, 25 cents (17); round steak, 8 pounds, $1.03 (28)	1.78	4.6	36	30	....	411
Pork: Sausage, 3.5 pounds, 35 cents (66)	.35	.9	5	18	....	180
Fish: Perch, 4 pounds, 25 cents (94)	.25	.6	3	1	....	21
Butter, 3 pounds, 80 cents (106)	.80	2.1	....	30	....	267
Eggs, 6.25 pounds, 76 cents (105)	.76	1.9	10	7	....	102
Milk, 19.89 pounds, 66 cents (114)	.66	1.7	8	9	12	160
Total animal food	4.60	11.8	62	95	12	1,141
VEGETABLE FOOD.						
Cereals: Apple pies, 3 pounds, 36 cents (158); bread, 9 pounds, 45 cents (147); cake (sweet), 0.5 pound, 5 cents (150); doughnuts, 1.13 pounds, 10 cents (156); flour, 24.5 pounds, 63 cents (122)	1.59	4.1	44	11	295	1,454
Sugar, 8 pounds, 46 cents (163)	.46	1.2	....	....	93	372
Vegetables: Cabbage, 4.94 pounds, 13 cents (181); onions (green), 0.94 pound, 15 cents (190); potatoes, 14 pounds, 23 cents (196); tomatoes (canned), 1.78 pounds, 10 cents (209)	.61	1.5	4	....	28	128
Total vegetable food	2.66	6.8	48	11	416	1,954
Total food	7.26	18.6	110	106	428	3,095

Table 15.—*Weights and cost of food and nutrients in dietary studies of American families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 38a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Porterhouse steak, 2.93 pounds, 41 cents (27); sirloin steak, 4.86 pounds, 68 cents (32); shoulder, 6 pounds, 60 cents (19).......	1.69	5.0	31	24	....	338
Pork: Ham, 1.25 pounds, 20 cents (60)..........	.20	.5	2	5	....	53
Fish: Whitefish, 2 pounds, 15 cents (103); lobster, 1 pound, 22 cents (90)....................	.37	1.1	4	1	....	25
Butter, 4 pounds, $1.25 (106)	1.25	3.7	1	45	....	405
Cheese, 1 pound, 16 cents (111)	.16	.5	3	4	....	48
Milk, 6.75 pounds, 60 cents (114).................	.60	1.8	3	4	5	68
Eggs, 1.5 pounds, 15 cents (105)..................	.15	.4	3	2	....	30
Total animal food	4.42	13.0	47	85	5	967
VEGETABLE FOOD.						
Cereals: Buns, 0.75 pound, 5 cents (148); crackers, 3 pounds, 38 cents (153); flour, 24.5 pounds, 60 cents (122)..............................	1.03	3.0	42	7	280	1,350
Sugar, 4 pounds, 24 cents (163).....................	.24	.7	....	....	53	212
Vegetables: Beans, 1.96 pounds, 8 cents (177); cabbage, 1.23 pounds, 8 cents (181); cucumbers, 1 pound, 10 cents (186); lettuce, 0.43 pounds, 5 cents (187); onions (dry), 1.25 pounds, 5 cents (189); onions (green), 0.5 pound, 5 cents (190); potatoes, 35 pounds, 68 cents (196)	1.09	3.2	15	1	87	417
Fruits: Bananas, 6 pounds, 30 cents (218); oranges, 4.75 pounds, 20 cents (238); strawberries, 1.3 pounds, 26 cents (250)........................	.76	2.3	1	1	18	85
Total vegetable food.............	3.12	9.2	58	9	438	2,064
Total food	7.54	22.2	105	94	443	3,031
Dietary study No. 39a.						
ANIMAL FOOD.						
Beef: Round steak, 3.6 pounds, 31 cents (28); shoulder steak, 4 pounds, 32 cents (19); porterhouse steak, 0.75 pound, 8 cents (27); shank (fore), 1 pound, 11 cents (17); suet, 0.5 pound, 5 cents (35). Veal, 3 pounds, 24 cents (37).....	1.11	2.2	19	13	....	192
Pork: Bacon, 1 pound, 20 cents (55); chops, 1 pound, 14 cents (58); sausage, 1 pound, 10 cents (66)	.44	.9	3	12	....	119
Butter, 1 pound, 25 cents (106)..................	.25	.5	....	7	....	62
Eggs, 12 pounds, $1.18 (105)	1.18	2.3	13	10	....	141
Butterine, 3 pounds, 51 cents (107)...............	.51	1.0	....	22	....	196
Milk, 37.69 pounds, $1.24 (114)...................	1.24	2.4	11	13	17	228
Total animal food.........................	4.73	9.3	46	77	17	938
VEGETABLE FOOD.						
Cereals: Bread, 2 pounds, 5 cents (147); buns, 0.75 pound, 5 cents (148); corn meal, 2 pounds, 5 cents (119); flour, 42.5 pounds, $1.05 (122); ginger snaps, 1 pound, 6 cents (157); graham meal, 5 pounds, 25 cents (124); oatmeal, 4 pounds, 15 cents (131); pop corn, 0.25 pound, 3 cents (132); wheat (cracked), 2 pounds, 15 cents (140)	1.84	3.6	61	10	388	1,885
Sugar, 4 pounds, 48 cents (163)....................	.48	.9	....	....	36	144
Vegetables: Asparagus, 2.81 pounds, 21 cents (174); beans (string), 0.66 pound, 5 cents (178); lettuce, 0.22 pound, 5 cents (187); potatoes, 14 pounds, 26 cents (196); radishes, 0.22 pound, 2 cents (200); rhubarb, 4 pounds, 10 cents (201)..	.69	1.4	3	....	20	92
Fruits: Apples, 8.33 pounds, 38 cents (214); lemons, 0.66 pound, 5 cents (236); oranges, 0.8 pound, 5 cents (238); plums, 2 pounds, 7 cents (245), raspberry jam, 1 pound, 10 cents (249)	.65	1.3	1	....	26	108
Total vegetable food........................	3.66	7.2	65	10	470	2,229
Total food..................................	8.39	16.5	111	87	487	3,167

Table 15.—*Weights and cost of food and nutrients in dietary studies of American families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 40a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Corned beef, 7 pounds, 48 cents (2); flank, 2 pounds, 10 cents (24); shoulder steak, 4.5 pounds, 42 cents (19); rump steak, 1.5 pounds, 15 cents (30). Mutton: Shoulder, 0.5 pound, 5 cents (51). Veal: Chuck, 2 pounds, 15 cents (37)	1.35	5.0	45	49	....	616
Pork: Bacon, 2 pounds, 20 cents (55); chops, 1 pound, 14 cents (58); lard, 0.5 pound, 6 cents (62); sausage, 2 pounds, 20 cents (66)	.60	2.2	10	48	....	467
Fish: White, 2.5 pounds, 25 cents (103); white (smoked), 0.5 pound, 5 cents (104)	.30	1.1	6	2	....	42
Butterine, 3 pounds, 45 cents (107)	.45	1.7	1	42	....	378
Eggs, 2.63 pounds, 35 cents (105)	.35	1.3	6	1	....	60
Milk, 9.42 pounds, 25 cents (114)	.25	.9	5	6	8	105
Total animal food	3.30	12.2	73	151	8	1,668
VEGETABLE FOOD.						
Cereals: Bread, 13 pounds, 64 cents (147); cake, 1.5 pounds, 10 cents (150); pie, 0.5 pound, 5 cents (158)	.79	3.0	22	6	136	685
Sugar, 5 pounds, 30 cents (163)	.30	1.1	....	....	81	336
Vegetables: Beans (string), 0.53 pound, 15 cents (178); lettuce, 0.66 pound, 5 cents (187); onions (dry), 1.25 pounds, 5 cents (189); potatoes, 14 pounds, 30 cents (196); turnips, 2 pounds, 5 cents (212)	.60	2.2	5	....	39	176
Total vegetable food	1.69	6.3	27	6	259	1,197
Total food	4.99	18.5	100	157	267	2,865
Dietary study No. 41a.						
ANIMAL FOOD.						
Beef: Rump steak, 6.78 pounds, 80 cents (30)	.80	3.5	20	25	....	303
Pork: Bacon, 0.5 pound, 8 cents (55); fresh pork, 4.75 pounds, 57 cents (58); sausage, 1 pound, 10 cents (66)	.75	3.3	16	39	....	411
Butter, 3 pounds, 90 cents (106)	.90	3.9	1	50	....	449
Milk, 14.66 pounds, 42 cents (114)	.42	1.8	10	11	15	198
Eggs, 7.5 pounds, 88 cents (105)	.88	3.8	19	14	....	201
Total animal food	3.75	16.3	66	139	15	1,562
VEGETABLE FOOD.						
Cereals: Bread, 13 pounds, 65 cents (147); cake, 0.75 pound, 10 cents (150); crackers, 1 pound, 10 cents (153); flour, 19.60 pounds, 55 cents (122); oatmeal, 1 pound, 5 cents (131)	1.45	6.3	74	12	463	2,255
Sugar, 14 pounds, 84 cents (163)	.84	3.7	....	....	276	1,104
Vegetables: Asparagus, 2.38 pounds, 25 cents (174); corn (canned), 3.93 pounds, 38 cents (184); potatoes, 42 pounds, 88 cents (195), spinach, 6.38 pounds, 23 cents (206)	1.74	7.6	21	2	142	670
Fruit: Jelly (cherry), 1 pound, 10 cents (223)	.10	.4	....	....	12	48
Beer, 1 pound, 5 cents (259)	.05	.2	....	....	2	8
Total vegetable food	4.18	18.2	95	14	895	4,085
Total food	7.93	34.5	161	153	910	5,647

DIETARY STUDIES OF GERMAN FAMILIES (Nos. 42a–44a).

The following three studies were those of the dietaries of German families who had lived for longer or shorter periods in this country.

DIETARY STUDY NO. 42A.

The family in this study consisted of three men, two women, and two children, respectively 13 and 8 years old, all in good health. The income of the family was $15 a week. They paid $30 a month rent for five rooms and a store. During the study they spent 70 cents for coffee, in addition to the food materials purchased.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Three men	63
Two women (42 meals × 0.8 meal of man) equivalent to	34
Child, 13 years (21 meals × 0.7 meal of man), equivalent to	15
Child, eight years (21 meals × 0.5 meal of man), equivalent to	11
Total number of meals equivalent to	123

Equivalent to one man forty-one days.

DIETARY STUDY NO. 43A.

This family consisted of two men, a woman, and two children, aged 2 years and 6 months, respectively. The children were very clean and were in good health, but the youngest child was rather pale. They were both allowed to drink tea and coffee. The income of the family was $12.50 a week. They paid $8.50 a month rent for three rooms. During the course of the study they spent 29 cents for tea and coffee and 10 cents for catsup.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Two men	42
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 2 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	67

Equivalent to one man twenty-two days.

DIETARY STUDY NO. 44A.

The family in this study consisted of one man, one woman, and three children, aged 13, 10, and 8 years, and weighing 90, 65, and 60 pounds, respectively. The woman and children looked well. The two older children drank a cup of coffee and a cup of tea each day. The youngest child drank milk. The income of the family was not given. They paid $45 a month rent for six rooms. Fuel cost them about $1 per week. In addition to the food materials purchased they spent 20 cents for tea, 35 cents for coffee, 30 cents for vinegar and catsup, and 5 cents for pickles.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 13 years (21 meals × 0.7 meal of man), equivalent to	15
Child, 10 years (21 meals × 0.6 meal of man), equivalent to	12
Child, 8 years (21 meals × 0.5 meal of man), equivalent to	10
Total number of meals equivalent to	75

Equivalent to one man twenty-five days.

TABLE 16.—*Weights and cost of food and nutrients in dietary studies of German families.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 42a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Round steak, 7 pounds, 70 cents (28); shoulder, 3.5 pounds, 35 cents (19); veal cutlets, 4 pounds, 50 cents (44)	1.55	3.8	30	14		245
Pork: Sausage, 1 pound, 10 cents (66)	.10	.2	1	5		49
Poultry: Fowl, 9.5 pounds, 95 cents (75); turkey, 9 pounds, 90 cents (76)	1.85	4.5	30	31		396
Fish: Sardines, 0.56 pound, 12 cents (99)	.12	.3	2	1		17
Butter, 5 pounds, $1.50 (106)	1.50	3.7	1	47		422
Eggs, 7.5 pounds, 79 cents (105)	.79	1.9	11	8		115
Cream, 7.5 pounds, 60 cents (113)	.60	1.5	2	15	4	158
Total animal food	6.51	15.9	77	121	4	1,402
VEGETABLE FOOD.						
Cereals: Bread, 16 pounds, 80 cents (147); flour, 2.25 pounds, 9 cents (122); rice, 1 pound, 5 cents (133)	.94	2.3	20	2	121	582
Sugar, 5.5 pounds, 33 cents (163)	.33	.8			61	244
Vegetables: Beans (dry), 3.92 pounds, 20 cents (177); cabbage, 2.47 pounds, 20 cents (181); onions (dry), 1 pound, 5 cents (189); potatoes, 8.75 pounds, 25 cents (196); radishes, 0.59 pound, 10 cents (200)	.80	1.9	12	1	43	229
Total vegetable food	2.07	5.0	32	3	225	1,055
Total food	8.58	20.9	109	124	229	2,457
Dietary study No. 43a.						
ANIMAL FOOD.						
Beef: Round, 1.5 pounds, 15 cents (28); shoulder, 2 pounds, 20 cents (19). Veal, breast, 4 pounds, 30 cents (36); leg, 2 pounds, 24 cents (39)	.89	4.1	33	15		266
Pork: Lard, 2 pounds, 26 cents (62); loin, 2 pounds, 24 cents (58); salt pork, 4 pounds, 24 cents (64); sausage, 0.66 pound, 10 cents (66)	.84	3.8	9	129	2	1,192
Eggs, 1.5 pounds, 20 cents (105)	.20	.9	4	3		43
Butter, 0.5 pound, 13 cents (106)	.13	.6		9		80
Milk, 14.66 pounds, 42 cents (114)	.42	1.9	10	12	15	207
Cheese, 0.9 pound, 18 cents (111)	.18	.8	5	6		73
Total animal food	2.66	12.1	61	174	17	1,861
VEGETABLE FOOD.						
Cereals: Bread, 9 pounds, 45 cents (147); cake, 0.75 pound, 15 cents (150); crackers, 1 pound, 8 cents (153); flour, 12.25 pounds, 33 cents (122); noodles, 1 pound, 12 cents (128)	1.13	5.1	51	9	329	1,600
Sugar, 6 pounds, 33 cents (163)	.33	1.5			123	492
Vegetables: Cabbage, 3.7 pounds, 21 cents (181); onions (green), 1.25 pounds 5 cents (190)	.26	1.2	1		5	24

TABLE 16.—*Weights and cost of food and nutrients in dietary studies of German families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 43a—Continued.						
VEGETABLE FOOD—continued.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Fruit, bananas, 3 pounds, 10 cents (218)	0.10	0.5	1	....	9	40
Beer, 1 pound, 5 cents (259)	.05	.2	....	....	2	8
Total vegetable food	1.87	8.5	53	9	468	2,164
Total food	4.53	20.6	114	183	485	4,025
Dietary study No. 44a.						
ANIMAL FOOD.						
Beef: Sirloin steak, 1.5 pounds, 20 cents (32); round steak, 1 pound, 12 cents (28); rib, 4 pounds, 50 cents (14); soup bone, 2 pounds, 10 cents (17). Mutton: Hind quarter, 5.75 pounds, 75 cents (47). Veal chuck, 2 pounds, 25 cents (37)	1.92	7.7	43	48	....	599
Pork: Chops, 2.5 pounds, 33 cents (58); lard, 1 pound, 14 cents (62)	.47	1.9	6	30	....	291
Fish: Trout (lake), 2 pounds, 25 cents (89); halibut (smoked), 2 pounds, 15 cents (86); salmon (whole), 1 pound, 20 cents (98)	.60	2.4	13	8	....	123
Butter, 2 pounds, 60 cents (106)	.60	2.4	....	31	....	276
Eggs, 4.5 pounds, 48 cents (105)	.48	1.9	11	8	....	115
Milk, 29.32 pounds, 91 cents (111)	.91	3.6	18	21	27	367
Total animal food	4.98	19.9	91	146	27	1,771
VEGETABLE FOOD.						
Cereals: Bread, 12 pounds, 62 cents (147); cake, 1 pound, 20 cents (150); flour, 12.25 pounds, 33 cents (122); oatmeal, 2 pounds, 15 cents (131)	1.30	5.2	53	9	319	1,568
Sugar and oil: Sugar, 5 pounds, 30 cents (163); sweet oil, 1 pound, 25 cents (171)	.55	2.2	....	18	91	524
Vegetables: Beans, 0.66 pound, 8 cents (177); corn, 1.31 pounds, 15 cents (185); lettuce, 0.66 pound, 15 cents (187); onions (green), 1.25 pounds, 5 cents (190); potatoes, 14 pounds, 30 cents (196); spinach, 1.6 pounds, 6 cents (206); rhubarb, 2 pounds, 12 cents (201)	.91	3.6	8	1	49	237
Fruits: Bananas, 3 pounds, 15 cents (218); pineapples, 3.81 pounds, 24 cents (243); strawberries, 0.65 pound, 13 cents (250)	.52	2.1	1	1	15	73
Total vegetable food	3.28	13.1	62	29	474	2,402
Total food	8.26	33.0	153	175	501	4,173

DIETARY STUDIES OF IRISH FAMILIES (Nos. 45a–50a).

The details of six studies with Irish families follow.

DIETARY STUDY NO. 45A.

The family in this study consisted of a man, weighing about 189 pounds, and two women, weighing about 143 pounds each. They were all in fair health. The income of the family was $125 a month. They paid $35 a month rent for seven rooms, one of which they rented. Their fuel cost them about $16 a month. During the course of the study they spent 18 cents for coffee and 15 cents for tea.

The study continued seven days. The family was away one day but there was a washerwoman present at two meals. The number of meals taken by the family may therefore be reckoned as follows:

	Meals.
Man	18
Two women (38 meals × 0.8 meal of man), equivalent to	30
Total number of meals equivalent to	48

Equivalent to one man sixteen days.

DIETARY STUDY NO. 46A.

This family consisted of three men, three women, and a child 12 years old; all in good health. The income of the family was $100 a month. They paid $13 a month rent for six rooms. During the period of the study they spent 65 cents for tea and 12 cents for yeast and pepper.

The study continued seven days. Two men took their lunches and one man his dinner away from home. Hence the number of meals taken was as follows:

	Meals.
Three men	42
Three women (63 meals × 0.8 meal of man), equivalent to	50
Child 12 years (21 meals × 0.7 meal of man), equivalent to	15
Total number of meals equivalent to	107

Equivalent to one man thirty-six days.

DIETARY STUDY NO. 47A.

This family consisted of a man, weighing about 180 pounds, and a woman, weighing about 140 pounds, and two children whose ages and weights were not given. The youngest child had been sick before the study began, but was well at the time. The older boy drank coffee and milk three times a day. The income of the family was $9 to $10 a week. They paid $5 a month rent for 2 rooms. Fuel cost them about 50 cents a week. In addition to the food materials purchased they spent 25 cents for coffee and 20 cents for tea.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child (21 meals × 0.5 meal of man), equivalent to	11
Child (21 meals × 0.3 meal of man), equivalent to	6
Total number of meals equivalent to	55

Equivalent to one man eighteen days.

DIETARY STUDY NO. 48A.

This family consisted of four men, one woman, and two children, aged 9 and 4 years, respectively. The children were in fair health.

They drank coffee in the morning and tea at night. The woman was dyspeptic and had bronchitis. The husband earned $9 a week, and $13 a week was received from boarders. They paid $11 a month rent for four rooms. In addition to the food materials purchased they spent $1.15 for tea and coffee and 3 cents for salt.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Four men	84
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 9 years (21 meals × 0.5 meal of man), equivalent to	11
Child, 4 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	120

Equivalent to one man forty days.

DIETARY STUDY NO. 49A.

The family in this study consisted of one man, 150 pounds, and three women weighing respectfully 125, 165, and 200 pounds. They were all in fair health. The income of the family was $8 to $9 a week. They paid $6 a month rent for three rooms. Fuel cost them about 50 cents a week. During the period of the study they spent 30 cents for tea and coffee.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Three women (63 meals × 0.8 meal of man), equivalent to	50
Total number of meals equivalent to	71

Equivalent to one man twenty-four days.

DIETARY STUDY NO. 50A.

This family consisted of four men, one woman, and two children, aged 14 and 6 years, respectively; all in good health. The husband earned $9 a week, and three boarders paid, respectively, $4.50, $4.25, and $4 per week. The family paid $12 a month rent for four rooms. During the period of the study they spent 30 cents for coffee, 10 cents for horseradish, and 5 cents for mustard.

The study continued 7 days. The number of meals taken was as follows:

	Meals.
Four men	84
Woman (21 meals ×0.8 meal of man), equivalent to	17
Child, 14 years (21 meals ×0.7 meal of man), equivalent to	15
Child, 6 years (21 meals ×0.5 meal of man), equivalent to	11
Total number of meals equivalent to	127

Equivalent to one man forty-two days.

Table 17.—*Weights and cost of food and nutrients in dietary studies of Irish families.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 45a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Sirloin steak, 2 pounds, 25 cents (32); veal rib, 6.25 pounds, 55 cents (43); liver, 0.50 pound, 5 cents (40); mutton rib, 1.5 pounds, 20 cents (46)	1.05	6.6	44	36	....	496
Pork: Bacon, 1 pound, 16 cents (55)	.16	1.0	3	17	....	163
Fish: White, 1.5 pounds, 15 cents (103)	.15	.9	5	1	....	29
Butter, 1 pound, 31 cents (106)	.31	1.9	....	21	....	214
Eggs, 3.25 pounds, 23 cents (105)	.23	1.4	12	8	....	119
Cream, 2.25 pounds, 20 cents (113)	.20	1.3	2	12	3	127
Milk, 4.19 pounds, 12 cents (114)	.12	.8	4	5	6	85
Total animal food	2.22	13.9	70	103	9	1,233
VEGETABLE FOOD.						
Cereals: Bread, 9 pounds, 45 cents (147); cakes, 0.5 pound, 5 cents (150)	.50	3.1	24	5	144	717
Sugar, 5 pounds, 25 cents (163)	.25	1.6	....	....	142	568
Vegetables: Tomatoes, fresh, 1 pound, 8 cents (211); lettuce, 0.22 pound, 5 cents (187); potatoes, 10 pounds, 20 cents (196); rhubarb, 3 pounds, 10 cents (201)	.43	2.7	6	....	45	204
Fruits: Bananas, 3 pounds, 10 cents (218); strawberries, 0.65 pound, 10 cents (250); pineapple, 0.9 pound, 15 cents (243)	.35	2.2	1	1	16	77
Total vegetable food	1.53	9.6	31	6	347	1,566
Total food	3.75	23.5	101	109	356	2,799
Dietary study No. 46a.						
ANIMAL FOOD.						
Beef: Liver, 2 pounds, 8 cents (8); sausage (smoked), 1 pound, 10 cents (16); flank steak, 1.5 pounds, 15 cents (24); rump (corned), 7 pounds, 56 cents (3); chuck, 11 pounds, $1.10 (23). Veal chops, 2.5 pounds, 28 cents (41). Mutton chops, 2.5 pounds, 33 cents (46)	2.60	7.2	54	54	....	697
Pork: Bacon, 1.25 pounds, 20 cents (55); ham, 1.33 pounds, 24 cents (60); lard, 2 pounds, 24 cents (62)	.68	1.9	4	39	....	363
Fish: White, 3 pounds, 33 cents (103); white (smoked), 2.5 pounds, 25 cents (104)	.58	1.6	10	6	....	93
Butter, 3 pounds, 90 cents (106)	.90	2.5	....	32	....	285
Eggs, 7.5 pounds, 85 cents (105)	.85	2.4	12	9	....	128
Cheese, 1 pound, 25 cents (111)	.25	.7	3	5	....	57
Milk, 21.98 pounds, 189 cents (114)	1.89	5.3	9	11	14	190
Total animal food	7.75	21.6	92	156	14	1,813
VEGETABLE FOOD.						
Cereals: Applepie, 1 pound, 12 cents (158); Bread, 2.2 pounds, 11 cents (147); cake, 2.25 pounds, 30 cents (150); crackers, 3 pounds, 29 cents (153); flour, 24.5 pounds, 72 cents (122)	1.54	4.3	44	11	325	1,574
Sugar, 8 pounds, 43 cents (163)	.43	1.2	....	....	101	404
Vegetables: Cabbage, 2.47 pounds, 16 cents (181); corn (canned), 1.31 pounds, 14 cents (184); onions (dry), 2.5 pounds, 14 cents (189); potatoes, 28 pounds, 60 cents (196); radishes, 0.65 pound, 10 cents (200); rhubarb, 1.5 pounds, 10 cents (201); tomatoes (canned), 1.78 pounds, 12 cents (209)	1.36	3.8	8	1	61	285
Fruit: Bananas, 6 pounds, 30 cents (218)	.30	.8	1	....	11	48
Total vegetable food	3.63	10.1	53	12	498	2,311
Total food	11.38	31.7	145	168	512	4,124

TABLE 17.—*Weights and cost of food and nutrients in dietary studies of Irish families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 47a.						
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Corned, 4 pounds, 30 cents (2); round steak, 2.5 pounds, 32 cents (28); sirloin, 2.5 pounds, 32 cents (32)	0.94	5.2	37	40	....	504
Pork: Bacon, 2 pounds, 26 cents (55); chops, 5 pounds, 25 cents (58); lard, 2 pounds, 24 cents (62); roast, 4.56 pounds, 54 cents (58)	1.29	7.2	38	142	....	1,416
Fish: Herring (fresh), 3 pounds, 18 cents (87)	.18	1.0	8	3	....	59
Butter, 1 pound, 24 cents (106)	.24	1.3	....	21	....	187
Eggs, 3 pounds, 32 cents (105)	.32	1.8	10	7	....	102
Milk, 12.56 pounds, 36 cents (114)	.36	2.0	10	13	16	220
Total animal food	3.33	18.5	103	226	16	2,488
VEGETABLE FOOD.						
Cereals: Apple pie, 1 pound, 10 cents (158); bread, 4 pounds, 20 cents (147); crackers, 0.5 pound, 4 cents (153); flour, 12.25 pounds, 29 cents (122); oatmeal, 2.5 pounds, 7 cents (131)	.70	3.9	57	13	347	1,732
Sugar, 4.88 pounds, 25 cents (163)	.25	1.4	....	....	123	492
Vegetables: Cabbage, 2.47 pounds, 12 cents (181); carrots, 0.25 pound, 3 cents (182); onions (green), 0.13 pound, 5 cents (190); potatoes, 14 pounds, 28 cents (196); turnips, 0.44 pound, 5 cents (212)	.53	3.0	7	....	56	252
Beer, 3.5 pounds, 18 cents (259)	.18	1.0	....	....	10	40
Total vegetable food	....	9.3	64	13	536	2,516
Total food	4.99	27.8	167	239	552	5,004
Dietary study No. 48a.						
ANIMAL FOOD.						
Beef: Corned, 12 pounds, 84 cents (2); rump steak, 15.5 pounds, $1.51 (30); shoulder, 15 pounds, $1.50 (19)	3.85	9.6	74	79	....	999
Pork: Chop, 2.5 pounds, 34 cents (58); sausage, 1 pound, 10 cents (66); sparerib, 4 pounds, 48 cents (58)	.92	2.3	11	24	....	258
Fowl, 8 pounds, $1.20 (75)	1.20	3.0	12	11	....	146
Fish: Salmon, 2 pounds, 30 cents (98); trout (lake), 4 pounds, 40 cents (89)	.70	1.7	8	4	....	68
Butter, 3 pounds, 80 cents (106)	.80	2.0	....	29	....	258
Eggs, 13.5 pounds, $1.44 (105)	1.44	3.6	20	14	....	205
Milk, 12.56 pounds, 36 cents (114)	.36	.9	5	6	7	101
Total animal food	9.27	23.1	130	167	7	2,035
VEGETABLE FOOD.						
Cereals: Apple pie, 5 pounds, 60 cents (158); bread, 24 pounds, $1.20 (147); buns, 5.75 pounds, 40 cents (148); cake, 1 pound, 10 cents (150)	2.30	5.8	32	14	214	1,109
Sugar, 9 pounds, 53 cents (163)	.53	1.3	....	....	102	408
Vegetables: Cabbage, 2.47 pounds, 12 cents (181); potatoes, 28 pounds, 60 cents (196)	.72	1.8	6	1	48	225
Beer, 7 pounds, 35 cents (259)	.35	.9	....	....	9	36
Total	3.90	9.8	38	15	373	1,778
Total food	13.17	32.9	168	182	380	3,813
Dietary study No 49a.						
ANIMAL FOOD.						
Beef: Dried, 2 pounds, 25 cents (4); round, 2.5 pounds, 25 cents (28); rump, 4 pounds, 30 cents (15). Mutton (rib), 3 pounds, 15 cents (46). Veal chuck, 4.5 pounds, 25 cents (37)	1.20	5.0	52	43	....	591
Pork: Lard, 1 pound, 12 cents (62); loin, 4 pounds, 50 cents (58)	.62	2.6	10	39	....	387
Fish: Herring (fresh), 3 pounds, 18 cents (87)	.18	.8	6	2	....	42
Butter, 1 pound, 30 cents (106)	.30	1.2	....	16	....	142

TABLE 17.—*Weights and cost of food and nutrients in dietary studies of Irish families*—Continued.

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
Dietary study No. 49a—Continued.						
ANIMAL FOOD—continued.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Eggs, 3 pounds, 32 cents (105)	0.32	1.3	7	5	....	73
Milk, 12.56 pounds, 36 cents (114)	.36	1.5	8	10	12	169
Cheese, 0.33 pound, 5 cents (111)	.05	.2	2	2	....	26
Total animal food	3.03	12.6	85	117	12	1,430
VEGETABLE FOOD.						
Cereal: Bread, 2 pounds, 10 cents (147); flour, 4.08 pounds, 10 cents (122); oatmeal, 2 pounds, 10 cents (131); apple pie, 1 pound, 10 cents (158)	.40	1.7	19	6	111	573
Sugar, 19.5 pounds, $1 (163)	1.00	4.1	....	....	369	1,476
Vegetables: Cabbage, 2.47 pounds, 13 cents (181); onions (green), 0.13 pound, 10 cents (190); potatoes, 21 pounds, 42 cents (196); turnips, 1.31 pounds, 11 cents (212)	.76	3.2	8	....	62	280
Total vegetable food	2.16	9.0	27	6	542	2,329
Total food	5.19	21.6	112	123	554	3,759
Dietary study No. 50a.						
ANIMAL FOOD.						
Beef: Corned, 7 pounds, 43 cents (2); round steak, 3 pounds, 36 cents (28); shoulder, 5 pounds, 40 cents (19)	1.19	2.8	26	26	....	335
Pork: Chops, 8 pounds, $1.05 (58); ham (boiled), 2 pounds, 40 cents (61); lard, 0.5 pound, 5 cents (62); sausage, 3 pounds, 38 cents (66)	1.88	4.5	20	47	....	498
Fish: White, 3 pounds, 18 cents (103)	.18	.4	3	1	....	21
Butterine, 1 pound, 18 cents (107)	.18	.4	....	9	....	80
Eggs, 3 pounds, 32 cents (105)	.32	.8	4	3	....	43
Milk, 12.56 pounds, 36 cents (114)	.36	.9	5	5	7	93
Cream, 0.56 pound, 5 cents (113)	.05	.1	....	1	....	9
Cheese, 0.5 pound, 8 cents (111)	.08	.1	2	2	....	26
Total animal food	4.24	10.0	60	94	7	1,105
VEGETABLE FOOD.						
Cereals: Bread, 15 pounds, 75 cents (147); cake, 4.5 pounds, 50 cents (150); pie, 1 pound, 12 cents (158); rolls, 5 pounds, 25 cents (159)	1.62	3.9	24	10	154	801
Sugar, 6 pounds, 36 cents (163)	.36	.9	....	....	65	260
Vegetables: Cabbage, 1.23 pounds, 10 cents (181); onions, 4.25 pounds, 25 cents (189); potatoes, 35 pounds, 75 cents (196); turnips, 1.75 pounds, 10 cents (212); tomatoes (canned), 1.78 pounds, 10 cents (209)	1.30	3.1	10	....	62	288
Fruit: Oranges, 2.38 pounds, 10 cents (258)	.10	.2	....	....	2	8
Total vegetable food	3.38	8.1	34	10	283	1,357
Total food	7.62	18.1	94	104	290	2,462

MISCELLANEOUS DIETARY STUDIES (Nos. 51a–60a).

The ten studies following were made with families of different nationalities.

DIETARY STUDY NO. 51A.

This study was made with an English family consisting of a man, weighing 146 pounds, and a woman, weighing 185 pounds, both in good health. The income of the family was $100 a month. They paid $21 a month rent for six rooms and a bathroom. Fuel cost them $2.50 a week. During the period of the study they spent 45 cents for coffee and 1 cent for yeast in addition to the food materials purchased.

The study continued seven days. The woman was away from one meal and the man from two; hence the number of meals taken was as follows:

	Meals.
Man	19
Woman (20 meals × 0.8 meal of man), equivalent to	16
Total number of meals equivalent to	35

Equivalent to one man twelve days.

TABLE 18.—*Weights and cost of food and nutrients in dietary study No. 51a.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Porterhouse steak, 8.65 pounds, $1.08 (27)	1.08	9.0	62	58	....	764
Pork: Ham (boiled), 0.5 pound, 10 cents (61)	.10	.8	4	4	....	52
Fowl, 4.2 pounds, 63 cents (75)	.63	5.3	22	20	....	266
Butter, 2 pounds, 58 cents (106)	.58	4.8	1	64	....	574
Eggs, 5.25 pounds, 53 cents (105)	.53	4.4	26	18	....	264
Cream, 0.68 pound, 6 cents (113)	.06	.5	....	5	1	49
Milk, 12.56 pounds, 36 cents (114)	.36	3.0	16	19	24	329
Total animal food	3.34	27.8	131	188	25	2,298
VEGETABLE FOOD.						
Cereals: Bread, 1 pound, 5 cents (147); crackers, 1.5 pounds, 20 cents (153); flour, 9.8 pounds, 24 cents (122)	.49	4.1	52	9	339	1,644
Sugar, 2 pounds, 16 cents (163)	.16	1.3	....	....	76	304
Vegetables: Asparagus, 5.63 pounds, 73 cents (174); cucumbers, 1 pound, 7 cents (186); peas (green), 1.36 pounds, 12 cents (194)	.92	7.7	6	1	13	85
Fruit: Strawberries, 0.65 pound, 11 cents (250)	.11	.9	....	....	1	4
Total vegetable food	1.68	14.0	58	10	429	2,037
Total food	5.02	41.8	189	198	454	4,335

DIETARY STUDY NO. 52A.

This family consisted of an Englishman, weighing 156 pounds, and a woman of Bohemian parentage, weighing 110 pounds. They were in tolerably good health. The woman was not very intelligent. Their income was $75 a month. They paid $11 a month rent for four rooms. The fuel cost them about 50 cents a week. During the period of the study they spent 25 cents for tea.

The study continued seven days, but the man had only one meal a day at home, so the number of meals taken was as follows:

	Meals.
Man	7
Woman (21 meals × 0.8 meal of man), equivalent to	17
Total number of meals equivalent to	24

Equivalent to one man eight days.

TABLE 19.—*Weights and cost of food and nutrients in dietary study No. 52a.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Porterhouse steak, 1.5 pounds, 15 cents (27); soup bone, 2 pounds, 5 cents (17). Veal chuck, 0.5 pound, 5 cents (37). Mutton: Shoulder, 0.5 pound, 5 cents (51)	0.30	3.7	40	27	....	400
Fish: White, 1.5 pounds, 10 cents (103): sardines, 0.28 pound, 5 cents (99)	.15	1.9	13	4	....	88
Butter, 0.25 pound, 9 cents (106)	.09	1.1	....	12	....	107
Eggs, 0.75 pound, 8 cents (105)	.08	1.0	6	4	....	60
Milk, 6.28 pounds, 18 cents (114)	.18	2.3	12	14	18	245
Total animal food	.80	10.0	71	61	18	900
VEGETABLE FOOD.						
Cereals: Bread, 3 pounds, 15 cents (147): flour, 1 pound, 3 cents (122)	.18	2.3	22	3	133	647
Sugar, 1 pound, 6 cents (163)	.06	.8	....	....	57	228
Vegetables: Asparagus, 0.56 pound, 5 cents (174); cabbage, 1.23 pounds, 10 cents (181); carrots, 1.38 pounds, 2 cents (182), lettuce, 0.44 pound, 6 cents (187); onions (green), 0.19 pound, 5 cents (190); potatoes, 7 pounds, 14 cents (196); rhubarb, 2 pounds, 5 cents (201)	.47	5.9	10	1	72	337
Fruit: Strawberries, 0.65 pound, 6 cents (250)	.10	1.3	....	....	3	12
Beer, 27 pounds, $1.35 (259)	1.35	16.9	8	....	176	736
Total vegetable food	2.16	27.2	40	4	441	1,960
Total food	2.96	37.2	111	65	459	2,860

DIETARY STUDY NO. 53A.

In this family the husband was English and the wife was American. The family consisted of two men, one woman, and two children aged, respectively, 6 years and 1 year. They were rather unintelligent and dirty, but in good health. The income of the family was $15 a week, not including the board of the second man. They paid $35 a month rent for four rooms and a store. For fuel they used soft coal, which cost them about 50 cents a week. During the course of the study they spent 80 cents for tea and coffee.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Two men	42
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 6 years (21 meals × 0.5 meal of man), equivalent to	11
Child, 1 year (21 meals × 0.3 meal of man), equivalent to	6
Total number of meals equivalent to	76

Equivalent to one man twenty-five days.

TABLE 20.—*Weights and cost of food and nutrients in dietary study No. 53a.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Soup bone, 2 pounds, 5 cents (17); sirloin steak, 2 pounds, 28 cents (32); beef (corned), 4 pounds, 28 cents (2); rib, 6 pounds, 75 cents (14). Veal chuck, 4 pounds, 32 cents (37). Mutton chops, 2 pounds, 25 cents (46)	1.93	7.7	53	62	....	764
Pork: Bacon, 2 pounds, 25 cents (55); chops, 2 pounds, 25 cents (58); sausage, 1 pound, 12 cents (66)	.62	2.5	11	39	....	391
Fish: Trout (lake), 2 pounds, 20 cents (89)	.20	.8	3	2	....	30
Butter, 2.5 pounds, 85 cents (106)	.85	3.4	....	39	....	347
Eggs, 9 pounds, 95 cents (105)	.95	3.8	21	15	....	218
Milk, 12.56 pounds, 30 cents (114)	.30	1.2	8	9	11	156
Cheese, 2 pounds, 20 cents (111)	.20	.8	9	12	1	147
Total animal food	5.05	20.2	105	178	12	2,053
VEGETABLE FOOD.						
Cereals: Bread, 8 pounds, 40 cents (147); oatmeal, 1 pound, 5 cents (131); rice, 2 pounds, 14 cents (133)	.59	2.4	19	3	118	575
Sugar, 4 pounds, 24 cents (163)	.24	1.0	....	....	73	292
Vegetables: Asparagus, 1.13 pounds, 20 cents (174); cabbage, 3.7 pounds, 16 cents (181); lettuce, 0.44 pound, 10 cents (187); onions (dry), 1 pound, 5 cents (189); onions (green), 0.13 pound, 5 cents (190); potatoes, 28 pounds, 50 cents (196); rhubarb, 2 pounds, 5 cents (201); turnips, 1 pound, 5 cents (212)	1.16	4.6	11	1	81	377
Fruits: Apples, 3.38 pounds, 10 cents (214); bananas, 9 pounds, 32 cents (218); strawberries, 2.6 pounds, 50 cents (250)	.92	3.7	2	1	33	149
Total vegetable food	2.91	11.7	32	5	305	1,393
Total food	7.96	31.9	137	183	317	3,446

DIETARY STUDY NO. 54A.

In this family the husband was of German descent, the wife was English. The whole family consisted of two men, a woman, and a child 10 years old. One of the men was not very well. The woman was attractive and intelligent. The boy was very well looking; he drank considerable milk. The income of the family was $25 a week. They lived in their own house, which would rent for about $20 a month. They spent 18 cents for coffee and 15 cents for tea during the course of the study.

The study continued seven days. One man was away from home for dinner. Hence the number of meals taken was as follows:

	Meals.
Two men	35
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 10 years (21 meals × 0.6 meal of man), equivalent to	13
Total number of meals equivalent to	65

Equivalent to one man twenty-two days.

TABLE 21.—*Weights and cost of food and nutrients in dietary study No. 54a.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Round steak, 2 pounds, 20 cents (28); porterhouse steak, 3 pounds, 48 cents (27)	0.68	3.1	20	15	....	214
Pork: Bacon, 0.56 pound, 10 cents (55); ham (boiled), 1 pound, 30 cents (61); salt pork, 0.5 pound, 6 cents (64)	.46	2.1	5	20	....	198
Eggs, 1.5 pounds, 16 cents (105)	.16	.7	4	3	....	43
Butter, 2 pounds, 60 cents (106)	.60	2.7	1	35	....	316
Milk, 14.66 pounds, 42 cents (114)	.42	1.9	10	12	15	207
Cream, 2.25 pounds, 21 cents (113)	.21	1.0	1	9	2	92
Total animal food	2.53	11.5	41	94	17	1,070
VEGETABLE FOOD.						
Cereals: Flour, 9.8 pounds, 28 cents (122); oatmeal, 1 pound, 5 cents (131)	.33	1.5	27	4	166	808
Sugar, 4 pounds, 24 cents (163)	.24	1.1	....	....	82	328
Vegetables: Beans (dry), 0.98 pound, 5 cents (177); corn (canned), 1.31 pounds, 15 cents (184); onions (dry), 1.5 pounds, 10 cents (189); potatoes, 14 pounds, 28 cents (196)	.58	2.6	11	1	62	301
Fruit: Bananas, 3 pounds, 15 cents (218)	.15	.7	....	....	9	36
Total vegetable food	1.30	5.9	38	5	319	1,473
Total food	3.83	17.4	79	99	336	2,543

DIETARY STUDY NO. 55A.

This study was made with a French-Canadian family consisting of a man, two women, and five children aged 14, 12, 10, 8, and 5 years, respectively. They were all in fair health. The woman was a dressmaker. The house was not neat. The income of the family was $30 a week. They paid $15 a month rent for six rooms. The fuel cost them $1.50 a week. During the course of the study they spent 62 cents for tea and coffee, 10 cents for salt and pepper, 2 cents for lemons, 1 cent for pickles, and 2 cents for soup greens. The woman frequently made meat ragout.

The study continued seven days. The man took his dinners away from home; hence the number of meals taken was as follows:

	Meals.
Man	14
Two women (42 meals × 0.8 meal of man), equivalent to	34
Child, 14 years (21 meals × 0.7 meal of man), equivalent to	15
Two children, 12 and 10 years (42 meals × 0.6 meal of man), equivalent to	25
Child, 8 years (21 meals × 0.5 meal of man), equivalent to	11
Child, 5 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	107

Equivalent to one man thirty-six days.

TABLE 22.—*Weights and cost of food and nutrients in dietary study No. 55a.*

Food consumed during the whole study (7 days).	Cost, nutrients, and fuel value of food per man per day.					
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Sirloin steak, 16 pounds, $1.70 (32); soup bone, 3 pounds, 18 cents (17). Veal chuck, 1 pound, 13 cents (37)	2.01	5.6	40	35	....	472
Pork: Sausage, 2 pounds, 25 cents (66); loin, 8.25 pounds, $1.05 (58); shoulder, 1.5 pounds, 22 cents (68); lard, 0.5 pound, 7 cents (62)	1.59	4.4	19	50	....	521
Fish: Trout (lake), 3 pounds, 36 cents (89)	.36	1.0	4	2	....	34
Butter, 4 pounds, $1.11 (106)	1.11	3.1	1	43	....	387
Eggs, 5.62 pounds, 71 cents (105)	.71	2.0	9	7	....	98
Milk, 17.8 pounds, 52 cents (114)	.52	1.4	7	9	11	152
Total animal food	6.30	17.5	80	146	11	1,664
VEGETABLE FOOD.						
Cereals: Bread, 24.25 pounds, $1.12 (147); cornstarch, 1 pound, 10 cents (172); crackers, 2 pounds, 15 cents (153); doughnuts, 18.55 pounds, $1.65 (156); flour, 2 pounds, 8 cents (122); macaroni, 1 pound, 15 cents (127); rice, 0.5 pound, 4 cents (133)	3.29	9.1	51	55	349	2,090
Sugars: Sugar, 6 pounds, 36 cents (163); sirup, 6 pounds, 20 cents (166)	.56	1.6	....	....	128	512
Vegetables: Lettuce, 1.32 pounds, 15 cents (187); onions (dry), 1.87 pounds, 8 cents (189); potatoes, 35 pounds, 63 cents (196); tomatoes, canned, 1.78 pounds, 10 cents (209); turnips, 0.44 pound, 5 cents (212)	1.01	2.8	9	.1	69	321
Total vegetable food	4.86	13.5	60	56	546	2,923
Total food	11.16	31.0	140	202	557	4,587

DIETARY STUDY NO. 56A.

The family in this study consisted of a man, a German, weighing 172 pounds, and a woman, an American, weighing 168 pounds; three children, aged, respectively, 14, 11, and 7 years, and weighing, respectively, 120, 90, and 48 pounds. The woman was intelligent and kept very careful records during the dietary study. She stated that she had received help regarding food and dietaries from talks at Hull House. She endeavored to provide a sufficient diet with good variety. The children were in good health. They drank milk and cocoa and a great deal of homemade root beer. The income of the family was $23 a week. They paid $11 a month rent for four rooms. The fuel cost them about 25 cents a week. During the course of the study they spent 35 cents for coffee, 30 cents for root-beer extract, 8 cents for yeast, 5 cents for salt, 4 cents for vinegar, and 1 cent for nutmeg.

The study continued seven days. In addition to the food consumed by the family they gave away the equivalent of one meal. The number of meals taken was therefore as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child, 14 years (21 meals × 0.7 meal of man), equivalent to	15
Child, 11 years (21 meals × 0.6 meal of man), equivalent to	13
Child, 7 years (21 meals × 0.5 meal of man), equivalent to	10
Food given away equivalent to	1
Total number of meals equivalent to	77

Equivalent to one man twenty-six days.

TABLE 23.—*Weights and cost of food and nutrients in dietary study No. 56a.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Rump (corned), 3.1 pounds, 24 cents (3); flank, 1.5 pounds, 15 cents (24); soup bone, 6 pounds, 22 cents (17); suet, 1 pound, 8 cents (35). Mutton, leg, 5.5 pounds, 63 cents (48)...	1.32	5.1	42	50	....	613
Pork: Salt pork, 0.5 pound, 6 cents (64)..........	.06	.2	....	8	....	71
Butter, 2 pounds, 62 cents (106)..................	.62	2.4	....	30	....	267
Eggs, 6 pounds, 64 cents (105)....................	.64	2.5	14	10	....	145
Milk, 29.32 pounds, 84 cents (114)................	.84	3.2	17	20	26	350
Cheese, 1 pound, 18 cents (111)	.18	.7	5	6	....	73
Total animal food	3.66	14.1	78	124	26	1,519
VEGETABLE FOOD.						
Cereals: Bread, 2 pounds, 10 cents (147); corn meal, 2 pounds, 5 cents (119); Graham meal, 2 pounds, 6 cents (124); oatmeal, 2 pounds, 10 cents (131); macaroni, 1 pound, 10 cents (127); rice, 2 pounds, 20 cents (133); white flour, 1 pound, 4 cents (122); whole-wheat flour, 9 pounds, 54 cents (123)..................	1.19	4.6	46	8	259	1,291
Sugars: Cocoa, 0.5 pound, 10 cents (168); sugar, 4 pounds, 22 cents (163)........................	.32	1.2	2	3	72	323
Vegetables: Beans (dry), 0.98 pound, 5 cents (177); cabbage, 1.23 pounds, 7 cents (181); carrots, 0.26 pound, 5 cents (182); cucumbers, 2 pounds, 8 cents (186); lettuce, 0.88 pound, 10 cents (187); onions (green), 5 pounds, 18 cents (190); peas (dry), 1.88 pounds, 5 cents (193); peas (green) 1.36 pounds, 10 cents (194); potatoes, 14 pounds, 25 cents (196); rhubarb, 2 pounds, 5 cents (201); spinach, 3.19 pounds, 20 cents (206)......................................	1.18	4.6	20	1	79	405
Fruits: Apples, 9 pounds, 35 cents (214); cocoanut (prepared), 1.5 pounds, 59 cents (224); figs, 1 pound, 10 cents (231); oranges, 4.75 pounds, 20 cents (238); prunes, 1 pound, 16 cents (247).....................................	1.31	5.0	4	16	56	382
Total vegetable food........................	4.00	15.4	72	28	466	2,401
Total food	7.66	29.5	150	152	492	*3,920

DIETARY STUDY NO. 57A.

This study was made with a Hungarian family consisting of three men, two women, and four children, aged, respectively, 14, 12, 10, and 2 years. The children were in fair health. They drank milk, tea, and coffee. The income of the family was not given. They paid $40 a month rent for 8 rooms. The fuel cost them about $1.50 a week. In addition to the food materials purchased they spent 67 cents for coffee, 50 cents for tea, 5 cents for soup greens, 5 cents for pickles, and 6 cents for candy.

The study continued seven days. Two of the men were away during the week. The number of meals taken was as follows:

	Meals.
Man..	21
Two women (42 meals × 0.8 meal of man), equivalent to............	34
Two children, 14 and 12 years (42 meals × 0.7 meal of man), equivalent to..	29
Child, 10 years (21 meals × 0.6 meal of man), equivalent to..........	13
Child, 2 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to..........................	105

Equivalent to one man thirty-five days.

TABLE 24.—*Weights and cost of food and nutrients in dietary study No. 57a.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Shoulder, 10 pounds, $1.09 (19); flank, 5 pounds, 37 cents (24); sirloin, 2.5 pounds, 30 cents (32); round, 2 pounds, 24 cents (28); suet, 5 pounds, 40 cents (35); shin, 2 pounds, 12 cents (17)	2.52	7.2	50	86	....	965
Butter, 4.5 pounds, $1.13 (106)	1.13	3.2	1	50	....	449
Eggs, 10.5 pounds, $1.10 (105)	1.10	3.2	18	13	....	188
Milk, 37.69 pounds, 95 cents (114)	.95	2.7	16	19	24	329
Cream, 6.72 pounds, 60 cents (113)	.60	1.7	2	16	4	166
Total animal food	6.30	18.0	87	184	28	2,097
VEGETABLE FOOD.						
Cereals: Apple pie, 1 pound, 10 cents (158); bread, 20 pounds, $1 (147); cakes, 2.70 pounds, 26 cents (150); crackers, 2 pounds, 17 cents (153); wheat breakfast food, 0.33 pound, 2 cents (137); flour, 9.5 pounds, 33 cents (122); oatmeal, 3 pounds, 11 cents (131); rice, 1 pound, 7 cents (133)	2.06	5.9	51	14	316	1,593
Sugar, 14 pounds, 77 cents (163)	.77	2.2	....	....	181	724
Vegetables: Beans (string), 2.63 pounds, 20 cents (178); cabbage, 2.47 pounds, 12 cents (181); carrots, 3 pounds, 5 cents (182); lettuce, 0.22 pound, 5 cents (187); onions, 2 pounds, 10 cents (189); peas (green), 2.75 pounds, 10 cents (194); potatoes (new), 7 pounds, 45 cents (196); radishes, 0.44 pound, 5 cents (200)	1.22	3.5	5	1	27	137
Fruits: Apples, 24 pounds, 60 cents (214); bananas, 3 pounds, 10 cents (218); peaches (dry), 1 pound, 15 cents (240); pears (dry), 1 pound, 10 cents (242); pineapples, canned, 3.81 pounds, 10 cents (244); prunes, 1 pound, 12 cents (247)	1.17	3.3	3	2	70	310
Total vegetable food	5.22	14.9	59	17	594	2,763
Total food	11.52	32.9	146	201	622	4,860

DIETARY STUDY NO. 58A.

This was a Bohemian family consisting of three men, two women, and four children, aged, respectively, 13, 11, 9, and 5 years. The children were in good health. They all drank coffee. The father earned $12 a week and boarders paid $3.50 a week each. The family rented a house of four rooms for $10 a month. They spent 54 cents for coffee in addition to the food materials purchased.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Three men	63
Two women (42 meals × 0.8 meal of man), equivalent to	34
Child, 13 years (21 meals × 0.7 meal of man), equivalent to	15
Child, 11 years (21 meals × 0.6 meal of man), equivalent to	13
Child, 9 years (21 meals × 0.5 meal of man), equivalent to	11
Child, 5 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	144

Equivalent to one man forty-eight days.

TABLE 25.—*Weights and cost of food and nutrients in dietary study No. 58a.*

Food consumed during the whole study (7 days).	Cost, nutrients, and fuel value of food per man per day.					
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Shin, 10.5 pounds, 53 cents (17). Mutton, leg, 7.5 pounds, 68 cents (48). Veal chuck, 8.5 pounds, 85 cents (37)	2.06	4.3	37	19	....	317
Pork: Sausage, 2 pounds, 20 cents (66); sparerib, 12.5 pounds, $1.44 (58)	1.64	3.4	18	39	....	419
Butter, 1.5 pounds, 43 cents (106)	.43	1.0	....	12	....	107
Eggs, 8.25 pounds, 83 cents (105)	.83	1.7	10	7	....	102
Milk, 21.99 pounds, 63 cents (114)	.63	1.3	7	9	11	152
Cheese, 1 pound, 5 cents (110)	.05	.1	2	....	....	8
Total animal food	5.64	11.8	74	86	11	1,105
VEGETABLE FOOD.						
Cereals: Flour (white), 19.6 pounds, 47 cents (122); flour (rye), 12.5 pounds, 27 cents (121)	.74	1.6	30	3	232	1,035
Sugar, 14 pounds, 77 cents (163)	.77	1.6	....	....	132	528
Vegetables: Beans (string), 5.25 pounds, 10 cents (178); cabbage, 2.47 pounds, 15 cents (181); carrots, 0.25 pound, 5 cents (182); lettuce, 1.25 pounds, 10 cents (181); onions, 1.25 pounds, 5 cents (189); potatoes, 3.5 pounds, 9 cents (196)	.54	1.1	2	....	11	52
Beer, 7 pounds, 35 cents (259)	.35	.7	....	....	8	32
Total vegetable food	2.40	5.0	32	3	383	1,687
Total food	8.04	16.8	106	89	394	2,792

DIETARY STUDY NO. 59A.

The family in this study consisted of a man, Irish, weighing 145 pounds, and a woman, English, weighing 109 pounds, and two children, one 6 years old, weighing 45 pounds, and one 4 years old, weighing 29 pounds. They were in fair health. The children drank tea and coffee three times a day. The income of the family was $9 a week. They paid $9 a month rent for three rooms. The fuel cost them 50 cents a week. In addition to the food materials purchased, they spent 60 cents for tea and coffee.

The study continued seven days. The number of meals taken was as follows:

	Meals.
Man	21
Woman (21 meals × 0.8 meal of man), equivalent to	17
Child (21 meals × 0.5 meal of man), equivalent to	10
Child, 4 years (21 meals × 0.4 meal of man), equivalent to	8
Total number of meals equivalent to	56

Equivalent to one man nineteen days.

TABLE 26.—*Weights and cost of food and nutrients in dietary study No. 59a.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Rump steak, 3 pounds, 33 cents (30); round steak, 1 pound, 10 cents (28); sirloin steak, 1.28 pounds, 18 cents (32); flank steak, 1.5 pounds, 15 cents (24); shoulder, 3.5 pounds, 46 cents (19); corned beef, 7 pounds, 49 cents (2); sausage (frankfurt), 0.5 pound, 5 cents (5). Veal chops, 1 pound, 15 cents (41)	1.91	10.1	71	79	....	987
Pork: Bacon (smoked), 1 pound, 12 cents (55); chops, 1 pound, 12 cents (58); lard, 1 pound, 12 cents (62); pork (salt), 1 pound, 14 cents (64)	.50	2.6	6	65	....	602
Fish, white, 2 pounds, 12 cents (103)	.12	.6	5	1	....	29
Butter, 2.5 pounds, 63 cents (106)	.63	3.3	1	51	....	458
Eggs, 4.25 pounds, 56 cents (105)	.56	3.0	13	9	....	132
Milk, 8.38 pounds, 24 cents (114)	.24	1.3	6	8	10	135
Cheese, 0.75 pound, 10 cents (111)	.10	.5	5	6	....	73
Total animal food	4.06	21.4	107	219	10	2,416
VEGETABLE FOOD.						
Cereals: Apple pie, 2 pounds, 24 cents (158); bread, 7 pounds, 30 cents (147); cake, 1.5 pounds, 30 cents (150); doughnuts, 1.13 pounds, 5 cents (156); flour, 24.5 pounds, 60 cents (122)	1.49	7.8	88	21	585	2,879
Sugar, 3 pounds, 18 cents (163)	.18	.9	....	....	72	288
Vegetables: Cabbage, 1.23 pounds, 8 cents (181); corn (canned), 1.31 pounds, 10 cents (184); cucumbers, 4 pounds, 10 cents (186); onions (dry), 5 pounds, 15 cents (189); onions (green), 0.75 pound, 25 cents (190); potatoes, 21 pounds, 45 cents (196); radishes, 0.66 pound, 5 cents (200); string beans, 1.97 pounds, 15 cents (178); turnips, 0.88 pound, 7 cents (212)	1.40	7.4	14	2	100	474
Total vegetable food	3.07	16.1	102	23	757	3,641
Total food	7.13	37.5	209	242	767	6,057

DIETARY STUDY NO. 60A.

This study was made with a Scotch family consisting of three men and a woman. The woman was in good health, but this was due to carefulness in diet, as she was not naturally strong. The income of the family was $20 a week and $9 a week from boarders. They occupied three rooms and a store, for which they were paying by installments, and which would rent for about $60 a month. In addition to the food materials purchased they spent 21 cents for coffee and 16 cents for tea.

The study continued seven days. Two men ate their lunches away from home each day. Hence the number of meals taken was as follows:

	Meals.
Three men	49
Woman (21 meals × 0.8 meal of man), equivalent to	17
Total number of meals equivalent to	66

Equivalent to one man twenty-two days.

TABLE 27.—*Weights and cost of food and nutrients in dietary study No. 60a.*

Food consumed during the whole study (7 days).		Cost, nutrients, and fuel value of food per man per day.				
Kinds and amounts.	Cost.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
ANIMAL FOOD.	*Dollars.*	*Cents.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Beef: Tenderloin steak, 3.25 pounds, 49 cents (32). Veal, neck, 7.75 pounds, 95 cents (42)	1.44	6.5	33	18	....	292
Pork: Bacon (smoked), 0.75 pound, 8 cents (55); chops, 1.5 pounds, 23 cents (58); sausage, 1.5 pounds, 18 cents (66)	.49	2.2	10	31	....	316
Butter, 2 pounds, 50 cents (106)	.50	2.3	....	35	....	312
Eggs, 7.5 pounds, 75 cents (105)	.75	3.4	20	15	....	214
Cream, 1.13 pounds, 10 cents (113)	.10	.5	1	4	1	42
Milk, 14.66 pounds, 35 cents (114)	.35	1.6	10	12	15	207
Total animal food	3.63	16.5	74	115	16	1,383
VEGETABLE FOOD.						
Cereals: Bread, 10 pounds, 58 cents (147); cake, 1 pound, 25 cents (150); crackers, 1 pound, 18 cents (153); pies, 2 pounds, 28 cents (158); rice, 0.5 pound, 4 cents (133)	1.33	6.1	25	10	163	841
Sugar, 2 pounds, 11 cents (163)	.11	.5	....	....	41	164
Vegetables: Beans (green), 0.66 pound, 7 cents (178); onions, 2 pounds, 10 cents (189); potatoes, 25 pounds, 50 cents (196); rhubarb, 3 pounds, 5 cents (201); spinach, 3.19 pounds, 10 cents (206); tomatoes (canned), 3.56 pounds, 24 cents (209)	1.06	4.8	12	1	87	405
Fruit: Bananas, 6 pounds, 25 cents (218)	.25	1.1	1	1	18	85
Total vegetable food	2.75	12.5	38	12	309	1,495
Total food	6.38	29.0	112	127	325	2,878

SUMMARY AND GENERAL DEDUCTIONS.

The results of the Chicago dietary studies are summarized in the following table:

TABLE 28.—*Summary of results of dietary studies with Chicago families.*

Dietary study No.	Families.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
		Cents.	*Grams.*	*Grams.*	*Grams.*	*Calories.*
29a	American, native	22.6	108	81	433	2,886
30a	.....do	26.3	105	133	489	3,560
31a	.....do	19.5	94	147	232	2,613
32a	.....do	31.6	119	135	458	3,510
33a	.....do	33.4	130	239	756	5,673
34a	.....do	30.3	138	191	356	3,677
35a	.....do	19.0	123	133	441	3,441
	Average	26.1	117	151	452	3,623
36a	American, German descent	29.9	119	152	340	3,189
37a	.....do	18.6	110	106	428	3,095
38a	.....do	22.2	105	94	443	3,031
39a	.....do	16.5	111	87	487	3,167
40a	.....do	18.5	100	157	267	2,867
	Average	21.1	109	149	393	3,070
41a	American, Irish descent	34.5	161	153	910	5,647
	Average all American families	24.9	117	139	465	3,566
42a	German	20.9	109	124	229	2,457
43a	.....do	20.6	114	183	485	4,025
44a	.....do	33.0	153	175	501	4,173
	Average	24.8	125	161	405	3,552

TABLE 28.—*Summary of results of dietary studies with Chicago families*—Continued.

Dietary study No.	Families.	Cost.	Protein.	Fat.	Carbohydrates.	Fuel value.
		Cents.	*Grams.*	*Grams.*	*Grams.*	*Calories.*
45a	Irish	23.5	101	109	356	2,799
46a	....do	31.7	145	168	512	4,124
47a	....do	27.8	167	239	552	5,004
48a	....do	32.9	168	182	380	3,813
49a	....do	21.6	112	123	554	3,759
50a	....do	18.1	94	104	290	2,462
	Average	25.9	131	154	441	3,660
51a	English	41.8	189	198	454	4,335
52a	English-Bohemian	37.2	111	65	459	2,860
53a	English-American	31.9	137	183	317	3,446
54a	German-English	17.4	79	99	336	2,543
55a	French-Canadian	31.0	140	202	557	4,587
56a	German-American	29.5	150	152	492	3,920
57a	Hungarian	32.9	146	201	622	4,860
58a	Bohemian	16.8	106	89	394	2,792
59a	Irish-English	37.5	209	242	767	6,057
60a	Scotch	29.0	112	127	325	2,878
	Average, all (32) studies	26.8	127	149	457	3,664

The cost of the diet per man per day varied in these studies from 16.5 cents in the lowest to 41.8 cents in the highest, but in most cases the range above or below the average, 26.8 cents, was considerably within these limits. In none of the Chicago studies was the expense as small as in two of the Philadelphia studies, but in three of the former it was larger than the largest among the latter.

In only three of the Chicago studies was the quantity of protein less than 100 grams per man per day. In two of these it was 94 grams and in one 79 grams. Probably in the latter case the figures should really be larger. One of the two men in the family was ill during the time of the study and doubtless ate less than he would when well, but in the calculations of the results of the study he has been credited with three full meals each day.

Concerning the dietary study No. 51a, with 189 grams of protein per man per day, and study No. 59a, with 209 grams, it has already been mentioned that the results are considered doubtful. Of the remaining studies the results of a few showed fairly large quantities of protein and energy per man per day, but the diet in the majority supplied not very far from the average of all the studies, namely, 127 grams of protein per man per day. This is practically the same as that of the commonly accepted American standard for a man at moderate muscular work, i. e., 125 grams per day. The energy of the average, 3,664 calories per man per day, is but 164 calories above that given by the standard just mentioned.

As in the case of the Philadelphia studies, the data concerning the occupations of the families were so few that but little can be said regarding the adequacy of the diet; but it may be inferred that it was sufficient. The families in these studies were more intelligent and were in better circumstances than were those in Philadelphia. They had regular incomes, which in a number of cases were more than enough to provide a comfortable living. It is therefore doubtless safe to assume that these people ate at least as much as they needed.

The Chicago families were on the whole rather less economical than those in Philadelphia. In the average of all the Chicago studies each cent spent secured 4.7 grams of protein and 137 calories of energy, while in the average of the Philadelphia studies there were 5 grams of protein and 144 calories of energy for each cent of the cost. As was the case in Philadelphia, the Chicago families also differed widely in respect to the economy of their purchases. Thus in study No. 31a the family spent 19.5 cents per man per day and secured 94 grams of protein and 2,613 calories of energy, while the family in study No. 35a for practically the same expenditure, 19 cents per man per day, obtained 123 grams of protein and 3,441 calories of energy. The family in study No. 39a secured 111 grams of protein and 3,167 calories of energy for 16.5 cents, while the family in study No. 52a obtained the same amount of protein, 111 grams, and about 300 calories less energy, or 2,860 calories, at a cost of about two and one-third times as much, 37.2 cents. There are several other examples of the fact that some of the families paid very much more than was necessary for the quantities of nutrients and energy obtained.

The costliness of the diets in these studies was not due to inability to purchase in quantities. Several of the articles used in these studies were bought in this way, the principal one being flour, which was bought in every case by the bag or barrel. The chief reason for the lack of economy in the purchase of food was inattention to or ignorance of the relation between the cost of food and its actual nutritive value.

COMMENTS AND CONCLUSIONS.

Something perhaps should be said regarding the results of the dietary studies in Philadelphia and Chicago, considered as a whole. It should be remembered that the studies were carried on some years ago, before some of the experimental methods at present followed had been devised. Furthermore, it was hardly possible with the limited time and equipment at the investigators' disposal to make an entirely satisfactory record of the foods purchased and eaten, and consequently, in many cases considerable dependence had to be placed upon information given by the families themselves. Certain errors are almost sure to occur in studies of this kind, even under favorable circumstances and with the most careful attention on the part of those conducting the investigations, especially under conditions like those attending the work in Philadelphia, where the families studied were almost without exception quite ignorant and untrained. The chief source of error lies in the possible tendency of the family to give a false impression of their food consumption; in some cases by purchasing larger quantities than usual or by reporting larger amounts than were actually purchased, and in other cases by omitting to mention some of the purchases made. For instance, it appears that families who had formerly been in more comfortable circumstances would sometimes be ashamed to let an outsider know how economically they were now living, and perhaps how insufficiently they were nourished. In such cases there might be a tendency to procure more food during the time of the study than ordinarily. Other families, suspecting an opportunity for pecuniary assistance, might be tempted to purchase less food than usual, or to conceal food already on hand. Another possible source of error is in the failure to make proper record of the number of meals taken by each member of the family or by any visitors.

It is noticeable that quite generally the results of dietary studies among poor families, where the statistics are recorded by the families themselves, indicate a larger food consumption than is found in the more reliable studies in which the food materials were actually weighed by those conducting the investigations. This was very forcibly illustrated by the results of dietary studies in Chicago in 1895 and 1896, described in a former publication of this Office.[a] In 25 studies in which the data were collected entirely by the investigators the average cost of the diet per man per day was 17.9 cents, and the average quantity of protein 116 grams, and of energy 3,160 calories. The persons in charge of these studies also conducted at the same time 28 others, in which the statistics were kept by the families themselves. These were made with families in the same localities and living under the same circumstances as the others, but the average cost of the diet per man per day as recorded was 22.1 cents, the average quantity of protein 147 grams, and of energy 3,550 calories. A comparison of the individual studies shows that where the statistics were furnished by the families the differences in results with different families were very much wider than in the studies made entirely by the investigators.

In the dietary studies in Philadelphia reported in these pages the families were not very intelligent and were in destitute circumstances; the chances for errors were therefore comparatively large. The families in the Chicago studies here reported were more intelligent and were in more comfortable circumstances, so that the possibilities of error in this case seem smaller. Bearing these facts in mind, it is evident that too sweeping conclusions should not be drawn from the results of the studies themselves or from the averages as compared with those of later studies of families in similar circumstances.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 55.

Considering the net results of these dietary studies they were of undoubted value to the settlement associations under whose auspices they were made. They furnished more accurate information than could have been gained otherwise regarding the ways of living, the adequacy of the diet, and the faults in methods of purchasing, cooking, and serving food. The information gained, it is believed, has been utilized in many ways to the advantage of all concerned.

Investigations like the above have been carried on in many other localities and under a variety of conditions. Of such work as a whole, it seems fair to say that it has materially assisted the attempts which have been made to help families like those studied in Philadelphia and Chicago to better methods of living.

APPENDIX.

As has been explained on preceding pages, the percentages of nutrients assumed for the different food materials used in the dietary studies reported in this bulletin are given in Table 29. These are taken mainly from a publication of this Office giving average values for the composition of American food materials,[a] but are included here in order that the present bulletin may contain all the data used in the composition of the results here reported.

The percentages of nutrients assumed for any food material used in the dietary studies may be found in the table below by means of the figures given in parentheses following the weights and cost of the food material in the detailed tables of the study in which it was used. The figures thus given in parentheses correspond with the figures in the column headed "Reference number" in Table 29.

In computing the fuel value of the studies the following factors were used: Protein 4, fat 8.9, and carbohydrates 4 calories per gram of the total nutrient. These are smaller than factors used in previous reports, namely, for protein and carbohydrates 4.1 and for fat 9.3 calories per gram, but the new factors are based upon later and much more complete data.

Table 29.—*Percentage composition of different food materials used in computing the nutrients of food in dietary studies in Philadelphia, Chicago, Boston, and Springfield.*

Ref. No.	Kind of food material.	Protein.	Fat.	Carbohydrates.
		Per cent.	*Per cent.*	*Per cent.*
	Beef:			
1	Bologna	18.2	19.7	....
1a	Brisket	12.0	22.3	....
2	Corned	14.3	23.8	....
3	Corned, rump	14.3	22.0	....
4	Dried	26.4	6.9	....
5	Frankfurters	19.6	18.6	1.1
6	Gelatin	91.4	.1	....
7	Heart	14.8	24.7	....
8	Liver	20.2	3.1	2.5
9	Neck	14.2	9.2	....
10	Rib roll	19.4	15.5	....
11	Roast, chuck	15.8	12.5	....
12	Roast, loin	16.4	16.9	....
13	Roast, pot (rump)	13.8	20.2	....
14	Roast, rib	14.4	20.0	....
15	Rump	15.2	18.6	....
16	Sausage	18.2	19.7	....
17	Shin (as lean shank)	13.2	5.2	....
18	Shin (as medium fat shank)	12.8	7.3	....

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 28, revised.

TABLE 29.—*Percentage composition of different food materials used in computing the nutrients of food in dietary studies in Philadelphia, Chicago, Boston, etc.*—Continued.

Ref. No.	Kind of food material.	Protein.	Fat.	Carbohydrates.
		Per cent.	*Per cent.*	*Per cent.*
	Beef—Continued.			
19	Shoulder and clod	16.5	8.4	....
20	Soup bone, fore shank	12.3	1.6	....
21	Soup bone, hind shank	9.7	3.9	....
22	Soup stock	5.8	1.5	....
23	Steak, chuck	15.3	11.1	....
24	Steak, flank	18.6	19.9	....
25	Steak, Hamburg	25.7	11.5	....
26	Do	19.0	12.8	....
27	Steak, porterhouse	19.1	17.9	....
28	Steak, round	19.2	9.2	....
29	Steak, round, lower cut	16.4	6.9	....
30	Steak, rump	15.2	18.6	....
31	Do	13.8	20.8	....
32	Steak, sirloin	16.5	16.1	....
33	Stew	16.5	8.4	....
34	Do	9.6	5.3	....
35	Suet	4.7	81.8	....
	Veal:			
36	Breast	15.7	8.2	....
37	Chuck	16.0	4.7	....
38	Heart	16.8	9.6	....
39	Leg	18.3	5.8	....
40	Liver	19.0	5.3	....
41	Loin	16.1	8.2	....
42	Neck	13.9	4.6	....
43	Rib	15.2	7.1	....
44	Round	20.1	7.5	....
	Mutton:			
45	Breast	15.4	19.1	....
46	Chops	13.1	31.5	....
47	Hind quarter	13.8	23.2	....
48	Leg	15.4	14.5	....
49	Liver	23.1	9.0	5.0
50	Neck	12.2	19.6	....
51	Shoulder	13.7	17.1	....
52	Shoulder, medium fat	13.7	15.5	....
	Lamb:			
53	As mutton shoulder	13.7	17.1	....
54	Leg	16.0	19.7	....
	Pork:			
55	Bacon	9.5	59.4	....
56	Bacon, fat	9.1	62.2	....
57	Bacon, lean	13.0	35.5	....
58	Chops	13.2	26.0	....
59	Fresh	13.4	24.2	....
60	Ham	14.3	29.7	....
61	Ham, boiled	20.2	22.4	....
62	Lard	....	100.0	....
63	Loin	13.4	24.2	....
64	Salt, fat	1.9	86.2	....
65	Salt, lean	7.4	59.6	....
66	Sausage	13.4	44.2	1.1
67	Scrapple[a]	3.3	18.3	11.2
68	Shoulders, smoked	12.6	33.0	....
69	Steak	14.3	29.7	....
70	Steak, ham	24.8	14.2	....
71	Tenderloin	18.9	13.0	....
72	Tripe	11.7	1.2	.2
	Poultry:			
73	Chicken fat	....	100.0	....
74	Duck	14.5	21.9	....
75	Fowl	13.7	12.3	....
76	Turkey	16.1	18.4	....
	Fish:			
77	Bluefish	10.0	.6	....
78	Clams	10.6	1.1	5.2
79	Cod, fresh	11.1	.2	....
80	Cod, salt (as purchased)	16.0	.4	....
81	Cod, salt (edible portion)	21.5	.3	....
82	Finland bloaters	20.5	8.8	....
83	Finnan haddie	22.3	2.3	....
84	Haddock	8.4	.2	....
85	Halibut, fresh	15.3	4.4	....
86	Halibut, smoked	19.3	14.0	....
87	Herring, fresh	11.2	3.9	....
88	Herring, smoked	20.5	8.8	....
89	Lake trout	9.1	5.1	....
90	Lobster	5.9	.7	.2
91	Mackerel	10.2	4.2	....
92	Do	11.6	3.5	....

[a] Estimated composition.

TABLE 29.—*Percentage composition of different food materials used in computing the nutrients of food in dietary studies in Philadelphia, Chicago, Boston, etc.*—Continued.

Ref. No.	Kind of food material.	Protein.	Fat.	Carbohydrates.
		Per cent.	*Per cent.*	*Per cent.*
	Fish—Continued.			
93	Oysters	6.1	1.3	3.3
94	Perch	7.3	1.5	....
95	Salmon	16.7	14.8	....
96	Salmon, canned	19.5	7.5	....
97	Salmon, salt	19.3	14.3	....
98	Salmon, whole	15.3	8.9	....
99	Sardines	23.7	12.1	....
100	Shad roe	20.9	3.8	....
101	Smelt	10.1	1.0	....
102	Smoked fish (as halibut)	19.3	14.0	....
103	Whitefish	10.6	3.0	....
104	Whitefish, smoked (as halibut)	19.3	14.0	....
105	Eggs	13.1	9.3	....
106	Butter	1.0	85.0	....
107	Butterine	1.2	83.2	....
108	Cheese, American	28.8	35.9	.3
109	Cheese, Camembert	25.9	33.7	2.4
110	Cheese, cottage	20.9	1.0	4.3
111	Cheese, full cream	25.9	33.7	2.4
112	Cheese, Neufchatel	18.7	27.4	1.5
113	Cream	2.5	18.5	4.5
114	Milk	3.3	4.0	5.0
115	Milk, skimmed	3.4	.3	5.1
	Cereals:			
116	Barley	8.5	1.1	77.8
117	Barley meal	10.5	2.2	72.8
118	Buckwheat	7.5	4.2	65.9
119	Corn meal	9.2	1.9	75.4
120	Corn meal, yellow	7.5	4.2	65.9
121	Flour, rye	6.8	.9	78.7
122	Flour, wheat—bread	11.4	1.0	75.1
123	Flour, wheat—entire wheat	13.8	1.9	71.9
124	Flour, wheat—graham	13.3	2.2	71.4
125	Flour, wheat—pastry	13.3	1.5	72.7
126	Hominy	8.3	.3	79.0
127	Macaroni	13.4	.9	74.1
128	Noodles	11.7	1.0	75.6
129	Oat breakfast food	15.5	7.4	66.8
130	Oatmeal	16.1	7.2	67.5
131	Oats, rolled	16.7	7.3	66.2
132	Popcorn (popped)	10.7	5.0	78.7
133	Rice	8.0	.6	79.0
134	Samp	8.3	.8	79.2
135	Spaghetti	12.1	.4	76.3
136	Wheat breakfast food	11.9	1.5	76.6
137	Do	11.8	1.0	76.3
138	Do	10.6	1.9	76.2
139	Do	10.7	1.4	75.1
140	Wheat, cracked	11.1	1.7	75.5
141	Wheat, germs	10.5	2.0	76.0
142	Wheatena	14.1	3.1	73.5
143	Wheat, shredded	10.5	1.4	77.9
144	Bread, Boston brown	5.4	1.8	47.1
145	Bread, graham	8.9	1.8	52.1
146	Bread, rye	9.0	.6	53.2
147	Bread, white	9.2	1.3	53.1
148	Buns	6.3	6.5	57.3
149	Buns, cinnamon	9.4	7.2	59.1
150	Cake	6.3	9.0	63.3
151	Cakes	7.0	9.7	73.7
152	Cookies, sugar	7.0	10.2	73.2
153	Crackers	10.7	8.8	71.9
154	Crackers, Boston	11.0	8.5	71.1
155	Crackers, soda	9.8	9.1	73.1
156	Doughnuts	16.7	21.0	53.1
157	Ginger snaps	6.5	8.6	76.0
158	Pie	3.1	9.8	42.8
159	Rolls	9.7	4.2	59.9
160	Rolls	8.9	4.1	56.7
161	Wafers, salted	10.6	12.7	68.5
	Sugars, starches, and oils:			
162	Sugar, brown	....	....	95.0
163	Sugar, white	....	....	100.0
164	Honey	.4	....	81.2
165	Molasses	2.4	....	69.3
166	Sirup	....	....	71.4
167	Chocolate	12.9	48.7	30.3
168	Cocoa	21.6	28.9	37.7
169	Irish moss (as tapioca)	.4	.1	88.0
170	Oil, cotton-seed	....	100.0	....

TABLE 29.—*Percentage composition of different food materials used in computing the nutrients of food in dietary studies in Philadelphia, Chicago, Boston, etc.*—Continued.

Ref. No.	Kind of food material.	Protein.	Fat.	Carbohydrates.
	Sugars, starches, and oils—Continued.	*Per cent.*	*Per cent.*	*Per cent.*
171	Oil, olive	....	100.0	....
172	Starch, corn	....	....	90.0
173	Starch, tapioca	0.4	.1	88.0
	Vegetables:			
174	Asparagus	1.8	.2	3.3
175	Beans, butter	4.7	.3	14.6
176	Beans, Lima	18.1	1.5	71.1
177	Beans, navy	22.5	1.8	59.6
178	Beans, string	2.1	.3	6.9
179	Beans, string, canned	1.1	.1	3.8
180	Beets	1.3	.1	7.7
181	Cabbage	1.4	.2	4.8
182	Carrots	.9	.2	7.4
183	Celery	.9	.1	2.6
184	Corn, canned	2.8	1.2	19.0
185	Corn, green	1.2	.4	7.7
186	Cucumbers	.7	.2	2.6
187	Lettuce	1.0	.2	2.5
188	Mushrooms	3.5	.4	6.8
189	Onions, dry	1.4	.3	8.9
190	Onions, green	.5	.1	5.5
191	Parsnips	1.3	.4	10.8
192	Peas, canned	3.6	.2	9.8
193	Peas, dried	24.6	1.0	62.0
194	Peas, green	3.6	.2	9.8
195	Peas, split	24.6	1.0	62.0
196	Potatoes	1.8	.1	14.7
197	Potatoes, Saratoga chips	6.8	39.8	46.7
198	Potatoes, sweet	1.4	.6	21.9
199	Pumpkins	.5	.1	2.6
200	Radishes	.9	.1	4.0
201	Rhubarb	.4	.4	2.2
202	Roman lettuce	1.0	.2	2.5
203	Salsify (as parsnips)	1.3	.4	10.8
204	Sauerkraut	1.7	.5	3.8
205	Soup greens	1.8	.4	1.7
206	Spinach	2.1	.3	3.2
207	Squash	.7	.2	4.5
208	Succotash, canned	3.6	1.0	18.6
209	Tomatoes, canned	1.2	.2	4.0
210	Tomatoes, conserve	.7	.1	57.6
211	Tomatoes, fresh	.9	.4	3.9
212	Turnips	.9	.1	5.7
213	Watercress	4.2	.6	6.3
	Fruits:			
214	Apples	.3	.3	10.8
215	Apple butter	.5	....	47.2
216	Apricots	1.0	....	12.6
217	Apricots, dried	4.7	1.0	62.5
218	Bananas	.8	.4	14.3
219	Barberry jelly	.5	....	63.8
220	Candied fruit (as marmalade)	.6	.1	84.5
221	Cherries, canned	1.1	.1	21.1
222	Cherry jelly	1.1	....	59.8
223	Do	1.2	....	59.8
224	Cocoanut, prepared	6.3	57.4	31.5
225	Crab-apple jelly	.5	....	61.7
226	Do	.4	....	65.8
227	Cranberries	.4	.6	9.9
228	Cranberry jelly	.4	....	64.0
229	Currants, dried	2.4	1.7	74.2
230	Dates	1.9	2.5	70.6
231	Figs	4.3	.3	74.2
232	Grapes	1.0	1.2	14.4
233	Grape jelly	.3	....	64.3
234	Grape fruit	.6	.1	8.5
235	Jelly	1.1	....	59.9
236	Lemons	.7	.5	5.9
237	Marmalade, orange	.5	....	74.4
238	Oranges	.6	.1	8.5
239	Peaches, canned	.7	.1	10.8
240	Peaches, dried	4.7	1.0	62.5
241	Pears	.5	.4	12.7
242	Pears, dried	2.8	5.4	72.9
243	Pineapples	.4	.3	9.7
244	Pineapples, canned	.4	.7	36.4
245	Plums, canned	1.8	....	62.2
246	Prunelles (as dried apricots)	4.7	1.0	62.5
247	Prunes, dried	1.8	....	62.2
248	Raisins	2.3	3.0	68.5

TABLE 29.—*Percentage composition of different food materials used in computing the nutrients of food in dietary studies in Philadelphia, Chicago, Boston, etc.*—Continued.

Ref. No.	Kind of food material.	Protein.	Fat.	Carbohydrates.
		Per cent.	*Per cent.*	*Per cent.*
	Fruits—Continued.			
249	Raspberry jam (as cherry jelly)	0.7	....	69.4
250	Strawberries	.9	0.6	7.0
251	Strawberries, preserved	.7	....	24.0
	Nuts:			
252	Almonds	21.0	54.9	17.3
253	Hickory nuts	5.8	25.5	4.3
254	Peanuts (as purchased)	19.5	29.1	18.5
255	Peanuts (edible portion)	25.8	38.6	34.4
256	Walnuts, English	6.9	26.6	6.8
257	Walnuts, English (edible portion)	18.4	64.4	13.0
258	Country pudding[a]	4.6	5.3	31.9
259	Beer[b]	.5	....	11.5

[a] Composition assumed.
[b] Alcohol computed to equivalent of carbohydrates.

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON THE FOOD AND NUTRITION OF MAN—Continued.

Bul. 84. Nutrition Investigations at the California Agricultural Experiment Station, 1896-1898. By M. E. Jaffa. Pp. 39. Price, 5 cents.

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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 130.

A. C. TRUE, Director.

EGYPTIAN IRRIGATION:

A STUDY OF IRRIGATION METHODS AND ADMINISTRATION IN EGYPT.

BY

CLARENCE T. JOHNSTON,
ASSISTANT CHIEF, IRRIGATION INVESTIGATIONS.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

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602

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 130.

A. C. TRUE, Director.

EGYPTIAN IRRIGATION:

A STUDY OF IRRIGATION METHODS AND ADMINISTRATION IN EGYPT.

BY

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CLARENCE T. JOHNSTON,

ASSISTANT CHIEF, IRRIGATION INVESTIGATIONS.

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

OFFICE OF EXPERIMENT STATIONS.

A. C. True, Ph. D., *Director.*
E. W. Allen, Ph. D., *Assistant Director.*

IRRIGATION INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., May 20, 1903.

Sir: I have the honor to transmit herewith and to recommend for publication a report on Egyptian irrigation, prepared under the direction of Elwood Mead, chief of irrigation investigations of this Office, by C. T. Johnston, assistant chief.

This report gives the results of observations made by Mr. Johnston during the winter of 1901–2 on the irrigation works, practices, and administrative system of Egypt, under authority of the act of Congress making appropriations for the irrigation investigations of this Office, which provides, among other things, for investigation and report upon "the laws * * * and institutions relating to irrigation and upon the use of irrigation water at home or abroad."

The bulletin is illustrated by twenty-five full page plate illustrations and nine text figures, all of which are necessary to a complete elucidation of the text.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., May 20, 1903.

Sir: I have the honor to submit herewith a report on Egyptian irrigation, prepared by Clarence T. Johnston, assistant chief of irrigation investigations of this Office. Mr. Johnston spent the winter of 1901–2 in Egypt, making a study of irrigation methods and laws. This report gives the results of his observations and inquiries.

In the valley of the Nile irrigation has been practiced for thousands of years, and if time and experience were in themselves sufficient we ought to find water distributed with more skill and used with better results there than in any other country. Such, however, is not the case. On the contrary, the irrigators of this country have little to learn from Egypt so far as practical methods are concerned. The reasons for this are not obscure. One is the lack of inventive and mechanical skill on the part of the fellah. Here every implement used in agriculture has been subject to constant change and improvement; the Egyptian still uses a crooked stick for a plow and beats out his corn as did his ancestors in the time of the Pharaohs. In this country we have already evolved special machinery for the construction of canals, building of laterals, and cleaning out and enlarging of ditches; in Egypt many canals are still cleaned by throwing the mud out by hand. The lessons of Egypt, therefore, so far as irrigation practice is concerned, are of negative value. There is another reason why this is so. Irrigators in Egypt are paid 15 cents a day. Their methods are possible only with this low wage rate, hence they can not be adopted in a country like ours, where higher wages are paid.

The showing of the yield and profits of irrigated land in Egypt is, however, full of significance and promise to the arid commonwealths. It is only on irrigated land that the average net return from sugar cane reaches $80 to $85 an acre. The revenues of the Egyptian Government from the areas devoted to dates runs from $10 to $45 an acre, and the net profit to the cultivator approximates $150 an acre. This little tract of agricultural land, no larger than the irrigable area of

California, supports between 5,000,000 and 6,000,000 people, pays the expenses of a costly government, and meets the interest on a national debt half as large as our own from the returns on agriculture alone.

Three subjects have a vital relation to the future extension of irrigation in this country. These are storage, drainage, and the utilization of water by pumping. The great storage works of Egypt have especial interest to our Government engineers; but Egypt has few examples of the small storage works such as are being built in large numbers by private parties in the West and which are destined to be an important feature of our irrigation systems. The accumulation of alkali in the surface soil, which has already become a troublesome feature in Western irrigation, at one time rendered unproductive large areas in lower Egypt. These are being reclaimed by drains which carry off the excess of salts and tend to prevent their further accumulation. So far as lifting water from wells or streams is concerned, the devices in Egypt are inferior to the gasoline and electric engines and centrifugal pumps now extensively used in the West. Some of the simpler and cheaper devices of Egypt are efficient for the lifting of small quantities of water, and there are many places in this country where such machines can be used to advantage.

Mr. Johnston's description of the dams built by the French and English Governments will have much interest. Their success from an engineering standpoint and the great benefits which have come to the people from this expenditure of government funds are unquestioned. But it is doubtful if we can adopt the administrative methods employed in Egypt. Political and economic conditions in that country differ so widely from our own that methods which are there useful are clearly inapplicable here. Egypt is governed by a foreign power, which has assumed arbitrary control over the water supply, recognizing no rights as belonging to the users of this water. Such a system has brought about an efficient use of the Nile, but it is repugnant to American ideas. It is a success in Egypt because of lack of means on the part of the agricultural population and lack of the experience in business and political affairs, needed for the successful operation of irrigation systems under private ownership. The American farmer has both the economic ability necessary to the management of irrigation works and the political power and the intelligence to create institutions for controlling the water supply which will be in harmony with our ideas of free government. The study of Egyptian laws and administrative methods, while interesting, is of little value as an example to be followed.

Respectfully submitted.

ELWOOD MEAD,
Chief of Irrigation Investigations.

A. C. TRUE, *Director.*

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EGYPTIAN IRRIGATION.

INTRODUCTION.

The studies on which this report is based were made during the winter of 1901–2 as a part of the work of the irrigation investigations of the U. S. Department of Agriculture. The object was not the compiling of an exhaustive treatise on Egyptian irrigation, but rather the study of agricultural practices, engineering works, and administrative measures for comparison with American works and methods, with a view to the improvement of the latter, giving especial attention to administrative methods.

The plan followed was to become conversant with the irrigation law of Egypt, then follow its application in the field. Such a study of irrigation administration can best be carried on with Cairo as a base. All the engineers having charge of the division of water have their offices there, and it is easy to reach any other part of the country from that city. Fortunately the laws had been compiled in French during the year 1901, and copies could be had for the asking.

The inspector of irrigation was absent from Cairo during the winter of 1901–2, and his duties were attended to by the inspectors of Lower and Upper Egypt. Under any circumstances these two officers and the chief of the technical department, who has charge of the installation of water-raising devices and the inspection of steam boilers used in connection with pumps, shoulder a large part of the responsibility. These officers gladly gave such information as they had in their possession, and referred such inquiries as they could not answer directly to those who were informed on the subject.

The great Nile dams would naturally be examined by one interested in irrigation, and the canals can be studied with profit. One feature of Egyptian irrigation which is almost lacking in America is the use of water-raising devices. The Egyptian farmer seldom is able to secure enough fall to permit the delivery of water by gravity alone. The problem of raising water from some of the streams of the United States will have to be solved in the near future. Wherever a river flows in a canyon or where the grade of a stream is small it is often advantageous to lift the water to the head of a canal instead of building a long or difficult line. It also makes the maintenance of large diversion works unnecessary. In view of these facts information was collected relating to the construction and cost of the devices employed, their efficiency, and cost of operation.

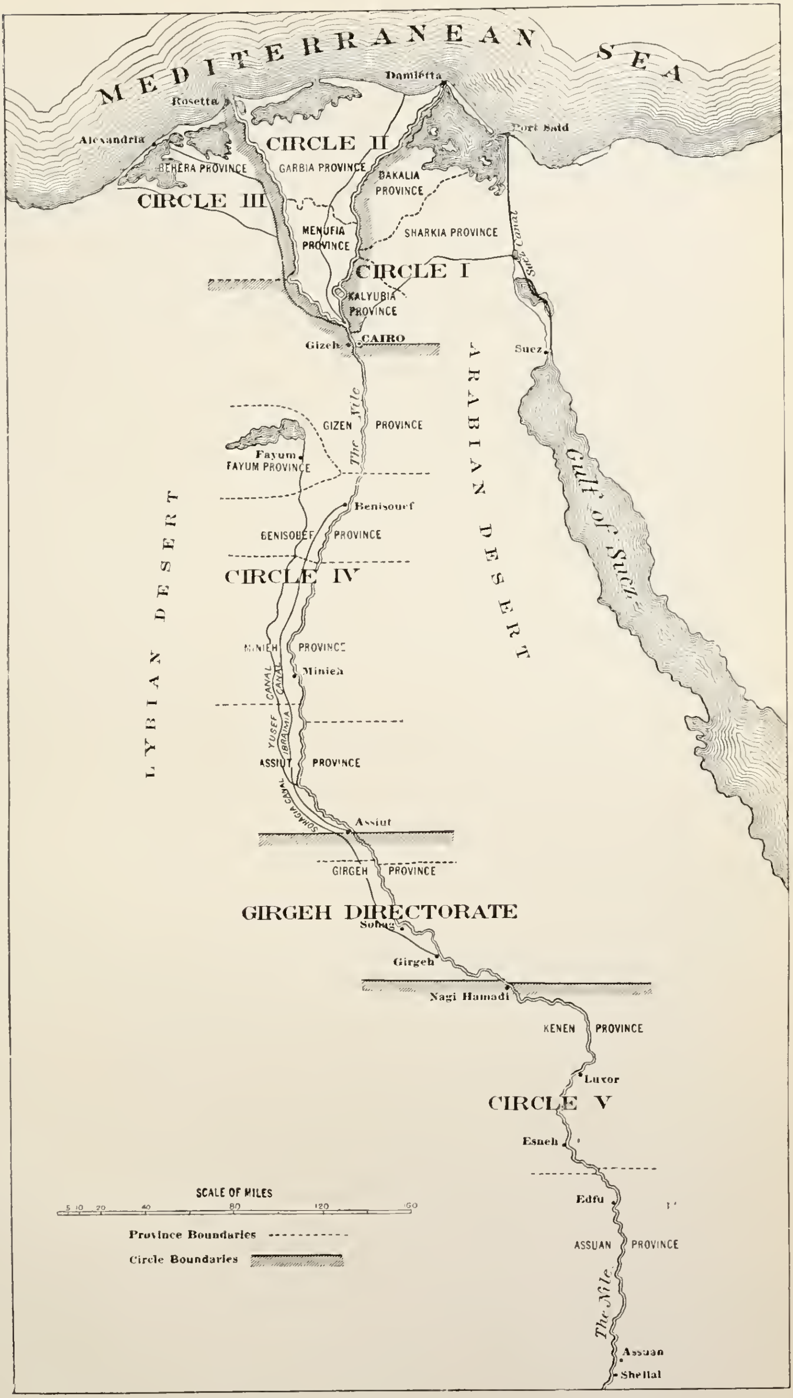
In Egypt as in America the use of water on the higher lands has ruined large areas of lower lands by raising the ground water, and with it the alkaline salts from the subsoil. Work for reclaiming these alkali lands has gone much farther in Egypt than in America, and Egyptian methods were, therefore, studied with much interest.

A GENERAL VIEW OF EGYPT.

Northern Africa would be an uninterrupted desert from the Atlantic to the Red Sea, except for a narrow strip bordering the Mediterranean, if it were not for the Nile. As it is, there is only a thread of arable land in the valley of the river, the surrounding desert being absolutely barren.

Egypt proper extends from Assuan to the Mediterranean. (See map, Pl. I.) South of Assuan is Nubia, which extends as far south as Khartum. The valley of the Nile is very narrow. But little cultivated country is found from Assuan to Luxor; the width of the valley between Assuan and Cairo varies from practically nothing to 9 miles, and there are a number of places where the desert touches the Nile on either bank, as at the point where the Gebel Silsileh hills cross the Nile. Between Edfu and Assuan there are many places where the drifting sands from the desert are encroaching upon the agricultural land. From Assuan to Edfu, a distance of about 90 miles, the agricultural land is about equally distributed on either bank. From Edfu to Erment, a distance of about 80 miles, the agricultural land is nearly all on the western shore, having an average width of 3 miles. From Erment to Assiut, over 200 miles, a large part of the agricultural land is on the left bank. From Assiut to Cairo the agricultural land is practically all on the left bank. At a point about 60 miles above Cairo the valley reaches its maximum width of about 9 miles, near where the Yusef Canal crosses the Lybian Desert into the Fayum. The delta proper begins some 12 miles below Cairo, and is triangular in shape, being nearly 120 miles on each side. The greater part of the irrigable land of Egypt lies in the delta, but only about half of the land that is actually farmed at the present time is found there. The remaining lands are being brought under cultivation by drainage and other reclamation works. The total agricultural area of Egypt is 5,000,000 acres or about four times the area of the State of Rhode Island.

The writer arrived in Alexandria in the early part of December, 1901. An Egyptian winter compares favorably with a Colorado summer. Everything is in summer garb, the vegetation being more attractive than it appears during the preceding hot months. Even the natives prefer the winter season, although they feel the chill of the night air and suffer from an occasional shower.


MEDITERRANEAN SEA
Damietta
Rosetta
Alexandria
Port Said
CIRCLE II
CIRCLE III
BEHERA PROVINCE
GARBIA PROVINCE
BAKALIA PROVINCE
MENUFIA PROVINCE
SHARKIA PROVINCE
Suez Canal
CIRCLE I
KALYUBIA PROVINCE
CAIRO
Gizeh
Suez
ARABIAN DESERT
Gulf of Suez
The Nile
GIZEH PROVINCE
Fayum
FAYUM PROVINCE
Benisouef
BENISOUEF PROVINCE
LYBIAN DESERT
CIRCLE IV
MINIEH PROVINCE
Minieh
YUSEF CANAL
IBRAIMIA CANAL
ASSIUT PROVINCE
SOHAGIA CANAL
Assiut
GIRGEH PROVINCE
GIRGEH DIRECTORATE
Sohag
Girgeh
Nagi Hamadi
KENEH PROVINCE
Luxor
CIRCLE V
Esneh
Edfu
ASSUAN PROVINCE
The Nile
Assuan
Shellal
SCALE OF MILES
5 10 20 40 80 120 160
Province Boundaries
Circle Boundaries

MAP OF EGYPT, SHOWING PROVINCES AND IRRIGATION CIRCLES.

After passing the custom-house at Alexandria and driving through narrow streets to the railway station the train for Cairo is boarded and soon the country is reached where palm trees wave their tops on either side. Lower Egypt in the vicinity of Alexandria is not attractive. Much of the land needs draining and a large part of that visible from the railway train is devoted to the growing of forage grasses. Open drains can be seen on either side and occasionally large canals parallel the track. The Mahmoudia Canal, which supplies the city of Alexandria with fresh water, lies on the north side of the railway and it is visible a part of the time during the first half-hour's ride toward Cairo. A roadway is provided on the banks of the canal and the native traffic is fully as interesting as the country through which the railway has been built. Long lines of camels loaded with cotton are followed by others carrying huge bundles of cotton stalks to be used for fuel. The stalks completely cover the camels so that it appears as if the burden furnished its own means of locomotion. The sails of the boats on the canal are seen when the banks of the canal are low or where the railway grade is high, and at times a view of the hulls and the cargoes is obtained. Cotton, fruit, straw, sugar cane, and vegetables seem to be the chief articles of exchange. Between 15 and 20 miles from Alexandria the first cotton fields are seen on the south side of the railway. Farther on camels are lying in the fields while the farmer loads on their backs farm products of different kinds in readiness for a trip to some nearby market. The cotton is pressed into bales, which are left on the ground to be carried later to a water front and thence to Alexandria. In quality the cotton is second only to American Sea Island cotton and the United States secures from 40 to 60 per cent of the entire Egyptian staple. The towns and villages are all on higher ground than is the surrounding farming land. This may be due in part to the selection of the site and in part to the gradual elevation of the villages as the buildings crumble and new ones are erected in their places. The markets are well supplied with fruits, among which the mandarin and other oranges seem to predominate. Dates, figs, bananas, and other fruits are common. The cultivated land grows richer as the Rosetta branch of the Nile is approached. The fig tree, the lebbek, the eucalyptus, and several varieties of the palm add much to the beauty of the landscape. Acacia trees of several varieties are seen here and there and the mulberry and numerous kinds of thorn trees abound. Vines of different kinds trail over buildings wherever conditions permit.

The Rosetta branch of the Nile is reached after a ride of nearly two hours. It is 63 miles by rail from Alexandria. The river is broad and is covered with craft of various kinds. Just beyond is the village of Kafr-ez-Zaiyat. The country greatly improves beyond the Rosetta branch of the Nile, and the farming scenes around Tanta can not be surpassed in Egypt. Farmers are in their fields cultivating the ground and cleaning away cotton stalks and other vegetation of the summer season. Here and there are oxen pulling wooden plows and farmers are cultivating by hand the land which can not be worked conveniently in any other way. Along some of the canals water-raising machines are in operation. Here and there two sturdy men are swinging a basket and lifting water from a canal for the irrigation of nearby farms. (See p. 44.) Herds of water buffalo, cattle, sheep, and occasionally horses can be seen grazing in the fields of clover.

A number of large canals, many of which are branches of the Manufia Canal, which leaves the Nile at the head of the delta, are seen from the train. The Damietta branch of the Nile is crossed, and after passing a few small towns and crossing a deep canal, which has been completed since the occupation by the English, the Pyramids, 20 miles away, come into view, and Cairo is reached.

Many interesting scenes can be witnessed in Cairo itself, showing the methods employed by farmers and gardeners. Between Cairo and Old Cairo to the south are a number of small tracts of farming land where the native may be seen at work. Across the river from Cairo a trolley line runs to the Pyramids of Gizeh. Along this for a distance of 6 or 7 miles one can see farmers working in the fields almost any time. The farms spread out on either side resemble but little those with which we are familiar in the United States. No fences are seen and no houses have been provided on the farms themselves. The farms are narrow, and it is impossible to use a mowing machine or a binder on some of them for this reason. Dwelling houses are found only in the villages, except where perennial irrigation has been practiced for many years.

Early in December wheat and barley are just sprouting from the ground in places while some lands are being prepared for the seed. Clover and beans are usually well advanced. Corn is piled here and there along the levees where it is to be husked during the later winter months. The fields of clover on either side are dotted with buffalo and other live stock. The farmer himself is a picture not to be forgotten. His long-flowing black or white gown, while not appearing to be designed for the convenience of a laborer, lends attractiveness to the farming scenes.

The view from any point along the road to the Pyramids is full of interest. To the east is the village of Gizeh, the Nile, and, beyond it, Old Cairo and the hills of the Arabian Desert on the horizon. Either to the north or south nothing can be seen but green fields, canals, levees, and villages of sun-dried brick, sheltered by palms and other trees. To the west is the Lybian Desert, the Pyramids of Gizeh, and the Sphinx. The latter looks over the farming lands below and across the Nile, as it has for 2,800 years. It is supposed to represent the king, Amenemhet III, the great builder and the reformer of the practice of irrigation in Egypt. It seems that the famous monument to him was planned so that it should be a permanent witness of the career of the fellah and of the progress of irrigation.

The fellah, although he has been ruled by one foreign power after another, has been almost as unchanging as his surroundings. Whether from lack of ingenuity or because he is satisfied with the appliances of his forefathers, the Egyptian makes very little progress in the construction or use of agricultural or scientific instruments. The writers of the hieroglyphs on the temples constructed four thousand or five thousand years ago might have received their inspiration from scenes in the fields to-day. The fellah plows his ground with a wooden plow or stirs it with a hoe or with a more primitive wooden implement. (Pl. II.) He cultivates the growing crops with a hoe and harvests them with a sickle or pulls the stalks from the ground by hand. The grain is either beaten out with a flail or trodden and chopped out by means of a wooden sledge furnished with rollers carrying disks and drawn by oxen. Egyptian agricultural methods would not look so much out of place were it not that at the present time considerable areas are owned by foreigners who have adopted modern methods. An improved thrashing machine may be at work in a field adjoining a plat where a native farmer is wearing out the straw in thrashing the grain by a primitive method which antedates biblical times. It is not uncommon to see a steam plow and one pulled by a camel and a buffalo working in adjoining fields. An immense modern steam pumping plant may be operated alongside a shaduf or a sakiyeh, and the native when interviewed will point with pride to the superior machine he employs.

After visiting the great barrage below Cairo and noting how the structure is maintained by the government, how it serves as a bridge across the Nile as well as a diversion work, how well the navigation interests of the Nile and the large canals have been conserved, and how beautifully the grounds of the southern extremity of the delta in the vicinity of the dam have been laid out in parks, the writer made arrangements to visit the Fayum province at the extremity of the Bahr Yusef Canal (the water of Joseph), some 75 miles southwest of Cairo. The province can best be reached by rail, going from Cairo 40 miles up the river to Wasta and there changing cars for the capital city, Medinet el Fayum. The morning fixed upon for the trip happened to be foggy and cold for Egypt. But little could be seen except the country lying near the railroad. Sugar cane, date-palm trees, and wheat fields abound and occasionally fields of clover and beans could be identified. After leaving Wasta it requires a run of only a few minutes to reach the margin of the cultivated lands. Soon the desert was entered and no sign of vegetation could be seen. Along the margin of the valley the hills break off abruptly and the country is rather rolling, but as soon as one leaves the slope toward the Nile the desert is comparatively flat and uninteresting.

After traversing the desert for about thirty minutes signs of cultivation began to appear. although the land showed that the water supply had not been adequate. As the soil is sandy, much water is needed to maintain plant growth. But few trees have been planted in this district and the houses of the farmers are scattered here and there, indicating that their location had not been fixed by any prearranged plan. As the flood of the Nile does not reach the Fayum, the village life so common in the valley of the Nile is not essential. As Medinet el Fayum is approached the country takes on new life and the soil changes to a black loam which yields all kinds of crops in abundance. The town is situated along the bank of Joseph's Canal, which furnishes the life of the province and adds much to the attractions of the town.

The country around the town is very productive, and affords an excellent opportunity for studying Egyptian agricultural methods. The entire province slopes toward a lake which lies along the margin of the desert to the northwest of the capital. The fall of the country is considerable, enabling the farmer to irrigate his field by gravity, as is done in the United States. Many lifting devices are found along the canals, however, which serve for the irrigation of lands lying adjacent to them. To the east of the town the canal is less attractive than it is within the limits of the capital, because it is more tortuous and the material which has been taken out in cleaning the channel has been deposited in heaps along the banks. The thrifty appearance of all growing crops is sufficient evidence of the fertility of the soil and the effectiveness of the irrigation system. Many trees seldom seen in the valley of the Nile can be found in this province. Among these the olive predominates. Date palms, oranges, and figs are extensively grown and the vine is well represented.

The conditions of the Fayum have changed but little, as far as we have any authentic history, since the time Lake Moeris disappeared to give place to an agricultural community. For over three thousand years the province has been cultivated and the people have enjoyed more of peace and prosperity than have the farmers in the valley of the Nile. The ruins of ancient Crocodilopolis lie to the south and west of the present capital, and to the east on the edge of the desert pyramids and ruins of immense temples are found.

In returning to Cairo the day was clear, and the entire panorama of desert and cultivated land was spread out as the train sped along. Farmers were out in the fields, some plowing with their curious wooden plows, others digging with the hoe, and others clearing the land or cleaning small ditches. Here and there steam plows belonging to some larger plantation took the place of the more primitive native implements. Drainage work was in progress in places, and occasion-

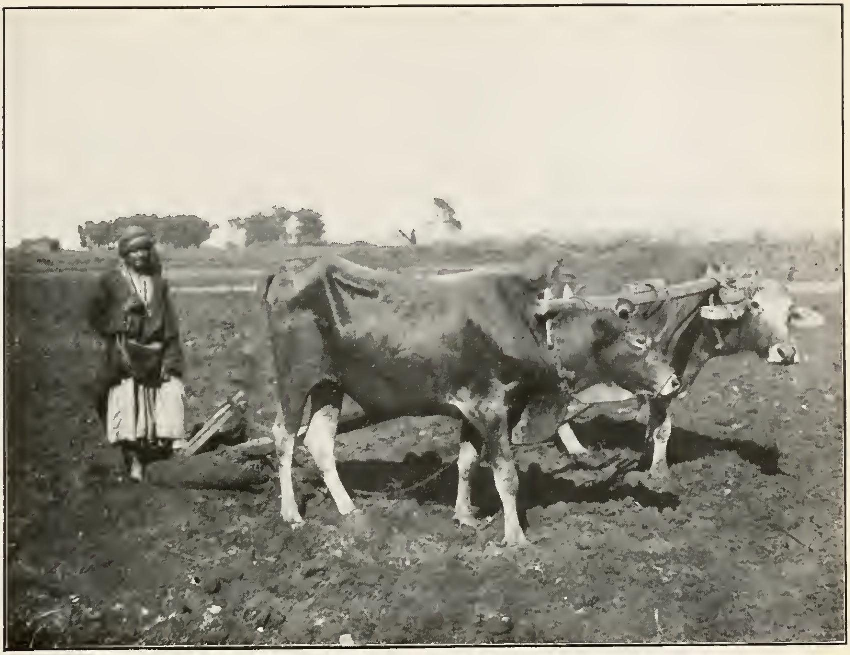


FIG. 1.—PLOWING WITH OX AND BUFFALO

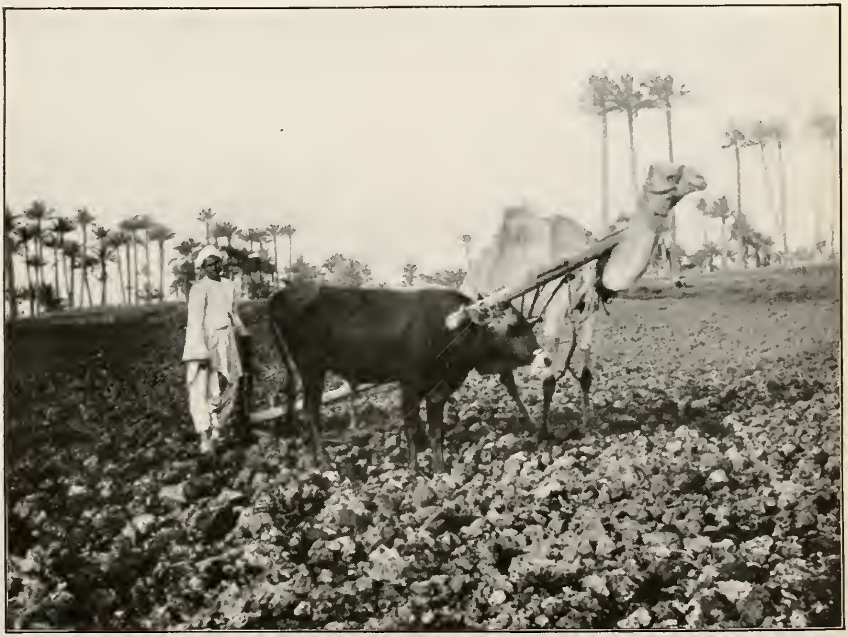
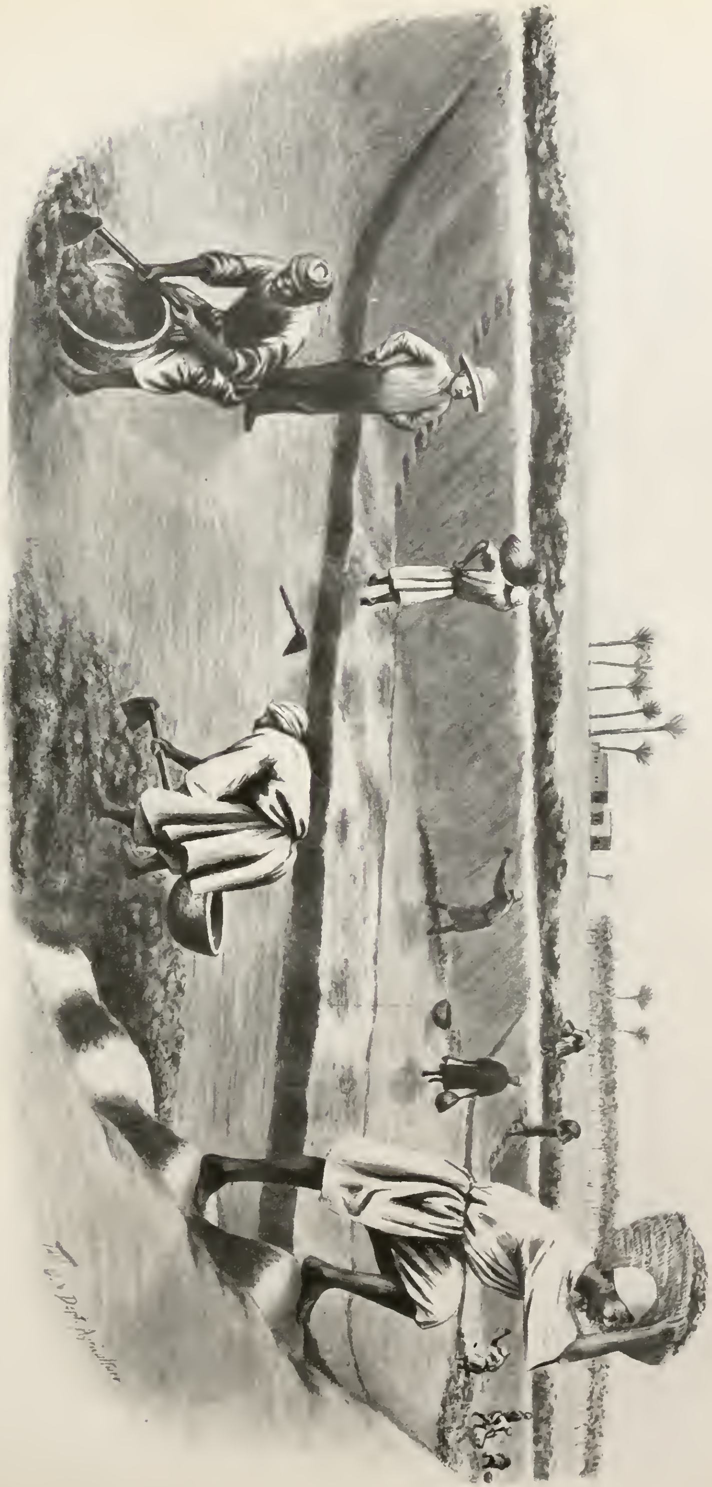


FIG. 2.—PLOWING LAND WHICH HAS BEEN BAKED BY THE SUN.



CLEANING A LARGE CANAL.

ally a piece of land was being leveled: crude wooden scrapers drawn by oxen were alternately filled from the higher places and emptied into the depressions. Some farmers had finished plowing and were driving oxen attached to heavy framework drags to break the clods and smooth the surface of the fields.

The journey from Cairo to Assuan can be made either by rail or by water. By rail one sees the canals and irrigated fields and the different methods employed in tilling the soil and cleaning water channels. By boat the diversion works at the heads of canals, the water-raising devices and irrigation structures near the river can best be studied. The journey by water has some advantages over the trip by rail. The boats have regular stopping places, where the surrounding country can be studied, and as the valley is in no place more than 9 miles wide, a considerable portion of the farming land between the river and the desert can be examined in a few hours.

Leaving Cairo in the morning by rail, Assuan is reached the next afternoon. The road runs south, on the west side of the river, paralleling the Ibraimia Canal as far as Assiut; it continues then to Nagi Hamadi, 373 miles from Cairo, where the river is crossed. The southern terminus of the road is at Chellal, 6 miles south of Assuan. Probably the most interesting part of the trip, to one making a study of irrigation and agriculture, is between Cairo and Assiut, a distance of 240 miles. The broad Ibraimia Canal parallels the railroad for some distance below Assiut. During the winter it is dry for a short time, when the channel is hurriedly cleaned. Laborers carrying baskets, which are filled by means of the hoe, swarm the banks and bottoms of the canal. The side slopes are formed accurately and smoothed with that instrument in a way seldom equaled in the United States. There are no plow marks along the banks and runways for teams are unnecessary, while the bare feet of the laborers tend to smooth rather than scar the surface of the ground. The material to be excavated has been cross-sectioned and each man or company of men is required to remove a certain volume. (See Pl. III.) The more industrious make the better wages.

The regulating works at Dirut can best be examined by stopping at the station for a few hours. These are representative of the best regulators in Egypt. Two large and two small canals begin at this place. The former are the Bahr Yusef and the Ibraimia canals, while the latter are the Dalgawi and Dirutieh canals. Running direct from the Nile and supplying water during the flood is the Saheliyeh Canal. The masonry works run from the point where this canal enters the channel above the regulators to the Ibraimia, thence to the Dirutieh, thence to the Bahr Yusef, and end just beyond the point where the Dalgawi Canal has its head. The works are substantially built and are maintained in good condition. One man can operate the gates of any of the canals by means of a traveling winch. On the east bank of the channel, about 500 feet above the entrance of the inlet gates of the Saheliyeh Canal, is a waste gate which discharges surplus water into a channel connecting with the Nile. The Dalgawi regulator has two gates, each nearly 10 feet wide. The Bahr Yusef has five, the Dirutieh has three, the Ibraimia has seven, and the entrance regulator of the Saheliyeh Canal has two gates. The wasteway has five gates. The latter, as well as the regulators of the two large canals, are supplied with locks which permit the passage of such boats as are employed on these waterways.

The Ibraimia Canal will henceforth be supplied at all times of the year from the new headworks at Assiut, which have been built in conjunction with the reservoir work at Assuan and the diverting dam at the former place. The latter structures are described elsewhere in this report.

The farming country becomes narrower as one ascends the river from Assiut. No perennial irrigation is practiced above Assiut except on the lands lying near the Nile, which are served by water-raising devices of various kinds. The Arabian desert breaks off abruptly on the eastern bank of the river in many places, and the principal areas of farming lands are found on the western side of the river.

Large sugar plantations are common, and at the principal towns sugar mills are in operation. Light railways have been built throughout Egypt wherever demand for transportation facilities warrants the outlay. These are narrow-gage roads, and the rolling stock is of the lightest.

The Sohag Canal, which was probably once a channel of the river, irrigates a large area between Assiut and the town of Sohag during the flood of the Nile. In the winter it lies high and dry, while the adjoining farms are green, as a result of inundation. At Dendera, farther up the river, where ruins of the celebrated temple bearing the same name have been found, the agricultural lands showed that a season of adequate water supply had been enjoyed. The temple was nearly buried by the crumbling mud bricks of a village which grew up about it, and has only recently been thoroughly excavated. The farming lands reach to the base of the temple, and during the flood season the water almost touches its foundation. The giant temple of Ammon at Karnak was originally surrounded by a high embankment, but this has been destroyed in places, so that now during the flood water stands to a considerable depth around it. The ruins cover an area 1,300 feet long and 400 feet wide, not counting some of the smaller and less important structures. The farms extend to the original protecting wall of earth. Between Karnak and Luxor can be seen an escape gate which is opened to permit the water of the basin to flow back into the Nile as high water recedes. Across the river the

Colossi of Memnon stand in a cultivated field watered by wells furnished with sakiyehs.

From Luxor to Assuan the valley contains but little of interest. The famous quarries where the Silsileh hills reach the water's edge on either side give one an idea of the immense quantity of stone which has been taken out for all kinds of masonry work. A narrow fringe of palm trees lines the banks of the river in many places, and the area of the agricultural land is limited on either side.

Assuan, lying on the right bank of the river just below the first cataract, is the Mecca of the traveler in Upper Egypt. The Elephantine Island, lying opposite the town, in the river; the rough, sterile deserts on either side; the granite points on land, and rocky islands in the rapid currents of the cataract each add to the interesting features in the vicinity of the town. The granite quarries in the desert to the east and north of Assuan show how that material was taken out in the early days of Egypt, and at the head of the cataract only 4 miles up the river one can see how through modern engineering appliances the same material is now handled. In less than four years the engineers of the Egyptian Government have built a dam containing 1,000,000 cubic yards of granite masonry. Machinery has supplanted slave labor; and where thousands of men were formerly required to transport large volumes of stone from one place to another the task is now easily accomplished by employing great derricks, steam engines, and improved quarry tools.

By the river it is but 4 miles from Assuan to the head of the cataract, where the great dam has been erected. A footpath follows the Nile, another passes through the desert in a direct line, while the railroad runs along a former channel of the river farther to the east. The dam is seen first if one goes by either footpath, while if the train is taken the island of Philae is in view as soon as the traveler alights at Chellal. No one can forget the first glimpse of this island and the temples with which its surface is covered. All other islands in the vicinity of Philae are high and rocky, while this particular one is flat and well adapted for the purpose to which it has been dedicated. Two miles downstream is the dam.

The engineers in charge of the construction of the dam were willing and anxious to explain the construction work in progress and make clear the function of the reservoir when completed. Some of the engineers had been at Assuan from the day the first work commenced. They enjoyed an ideal climate during the winter, but suffered much from the continuous heat of the summer. The thermometer ranges above 100° F. in the shade between the early spring and late fall months. It often reaches 120° and at times 130° during the summer. But little relief is afforded at night, as the granite rocks give off the heat they have absorbed during the day.

Ten thousand workmen were engaged on the construction of the dam during the winter of 1901–2. These men were poorly paid compared with the wages of those employed on similar work in the United States. They furnished their own subsistence and no shelter had been provided for them.

The best view of the dam is obtained from a position on the left bank of the river, just downstream of the structure. From this point its entire length is visible. Over it can be seen the neighboring islands in the river, beyond which is Philae and its ruined temples. In the foreground are numerous islets which break the river into many small waterways.

THE NILE.

The Nile is among the longest rivers in the world, being in this respect in the same class with the Amazon, the Kongo, and the Mississippi, but in discharge it is much below many rivers having shorter courses. The following comparison of the discharges of large rivers shows the relative position occupied by the Nile:

Comparison of discharges of the Nile, Ganges, Irrawaddy, Brahmaputra, and Mississippi rivers.

River.	Length.	Discharge.			Drainage area.
		Maximum.	Minimum.	Mean.	
	Miles.	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*Cubic ft. per sec.*	*Square miles.*
Nile (at Assuan)	3,300	459,000	10,000	128,000	1,300,000
Ganges (British India)	1,557	494,000	36,000	141,000	391,000
Irrawaddy (Burma)	2,532	[a] 1,000,000	[a] 84,000	350,000	150,800
Brahmaputra (British India)	1,700	1,800,000	146,000	520,000	361,300
Mississippi (at St. Louis) [b]	4,200	994,000	33,000	126,000	1,226,400

[a] Estimated.

[b] Head of Missouri to mouth of Mississippi.

The White Nile rises in Lake Victoria, in central Africa, and flows northerly, emptying into the Mediterranean, 3,300 miles from its source. From Lake Victoria to Khartum, where it unites with the Blue Nile, is a distance of 2,100 miles. The only tributary flowing into the Nile below the junction of the two main feeders is the Atbara River, about 190 miles farther north. Both the Atbara and Blue Nile rise in the Abyssinian Mountains and flow northwesterly. From the point where the Saubat River joins the White Nile, 2,370 miles from the Mediterranean, only two tributaries add to its discharge, and for more than 1,600 miles the river passes through an absolutely barren country. Even after it enters Egypt the width of the cultivated land can almost be disregarded in comparison with the broad expanse of desert on either side.

High water of the White Nile appears during June, and the flood does not recede until October. It furnishes a more uniform flow to the irrigators of Nubia and Egypt than any other tributary. It derives its supply from the heavy rains in the equatorial regions where it has its source. The high-water season of both the Blue Nile and the Atbara begins with July and ends with September. These two streams furnish nearly all of the sediment which has built up the valley of the river in Egypt and maintained the fertility of the soil. The effect of the high water from all sources is felt at Cairo soon after the 1st of August, but owing to the demand for water in upper Egypt during the late summer and early fall months extreme high water does not reach Cairo until toward the end of September, when the basins have discharged into the river.

While the Nile varies each year in discharge it is a singularly steady stream, and in this respect is unlike the rivers with which we are familiar. It has but one high-water season each year, and this begins and ends so regularly that irrigators know when to prepare for the flood. Although the stream is remarkable in this respect, its variations in discharge in different years affect agriculture greatly. During years of low Nile large areas go unirrigated. In average years the Nile furnishes sufficient water to bring prosperity to Egypt. Once in fifteen or twenty years it is unusually high, when large areas are devastated by floods. If a sudden rise should occur in the Nile, as so often happens in many of our Western streams, it would be a great curiosity to the natives.

The accompanying chart (fig. 1) makes a comparison between the discharge of the Nile at Assuan and of the Mississippi at St. Louis. It will be seen that the discharge of the Mississippi is very irregular. High water may appear at St. Louis at any time between April and June, and this maximum discharge may range from 250,000 to nearly 1,000,000 cubic feet per second. The maximum discharge of the Nile varies from 300,000 to 420,000 cubic feet per second. If the Nile varied as the Mississippi does at St. Louis, agricultural Egypt would soon cease to exist, unless the great volumes of water which would descend at flood times could be stored and the flow of the river equalized.

Fig. 2 shows the relation between the discharge of the Nile at Assuan and of the Missouri at Kansas City for the four years beginning with 1897, giving the maximum, minimum, and mean yearly discharges for these four years. Both streams flow through arid countries. The Nile rises in a region of tropical rains, although a considerable portion of its supply comes from the Abyssinian Mountains and the ranges of central Africa. The Missouri has its source in the snow-covered Rockies. It will be noticed that the high-water period of the Missouri may occur at almost any time between the middle of April and the 1st of July, while the Nile reaches its maximum near the 1st of September. The discharge of the two streams is about the same during January and February and during the first

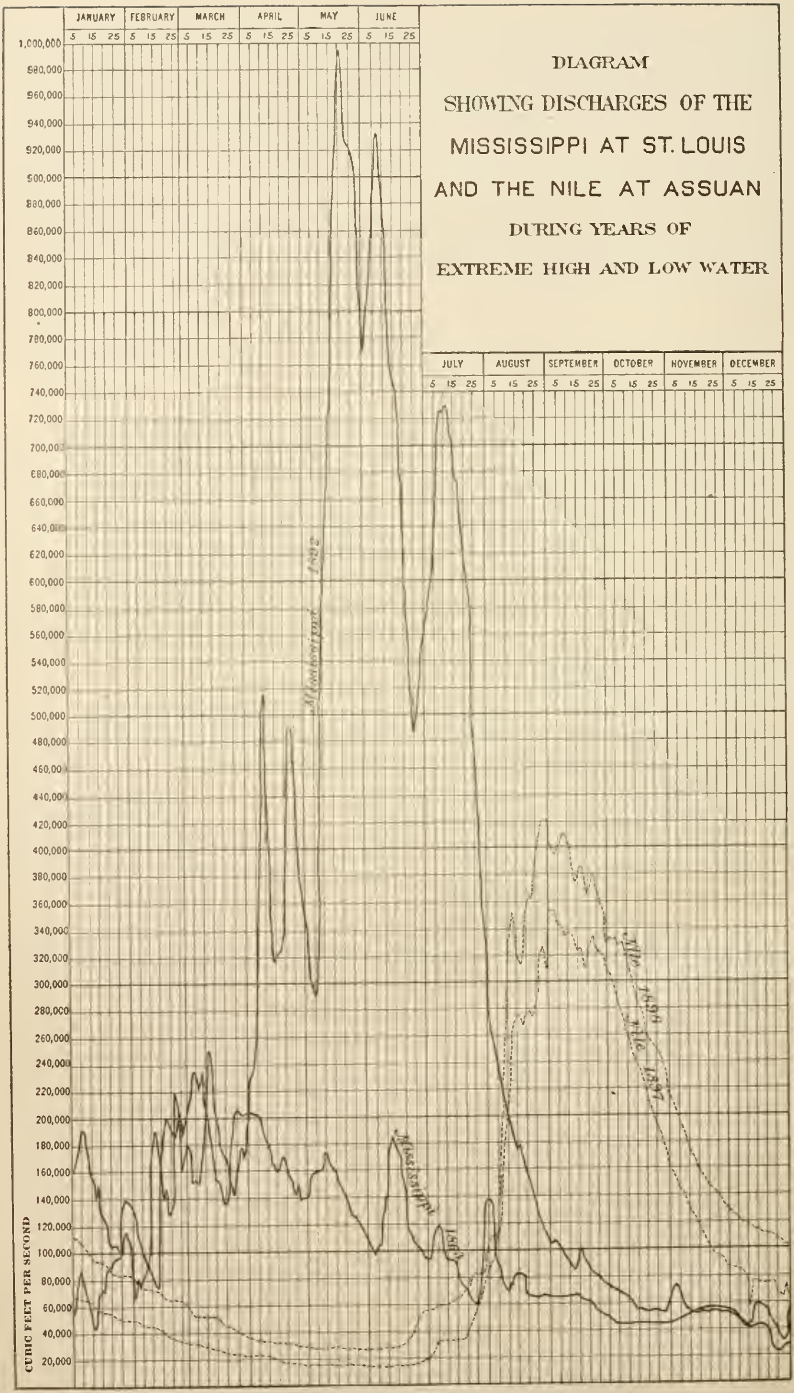


FIG. 1.—Diagram showing discharges of the Mississippi at St. Louis and of the Nile at Assuan.

part of August. It will be observed that the discharge of the Nile is comparatively uniform, while that of the Missouri is exceedingly irregular. The absence of great fluctuation in the discharge of the Nile can probably be explained by the fact that there are but few

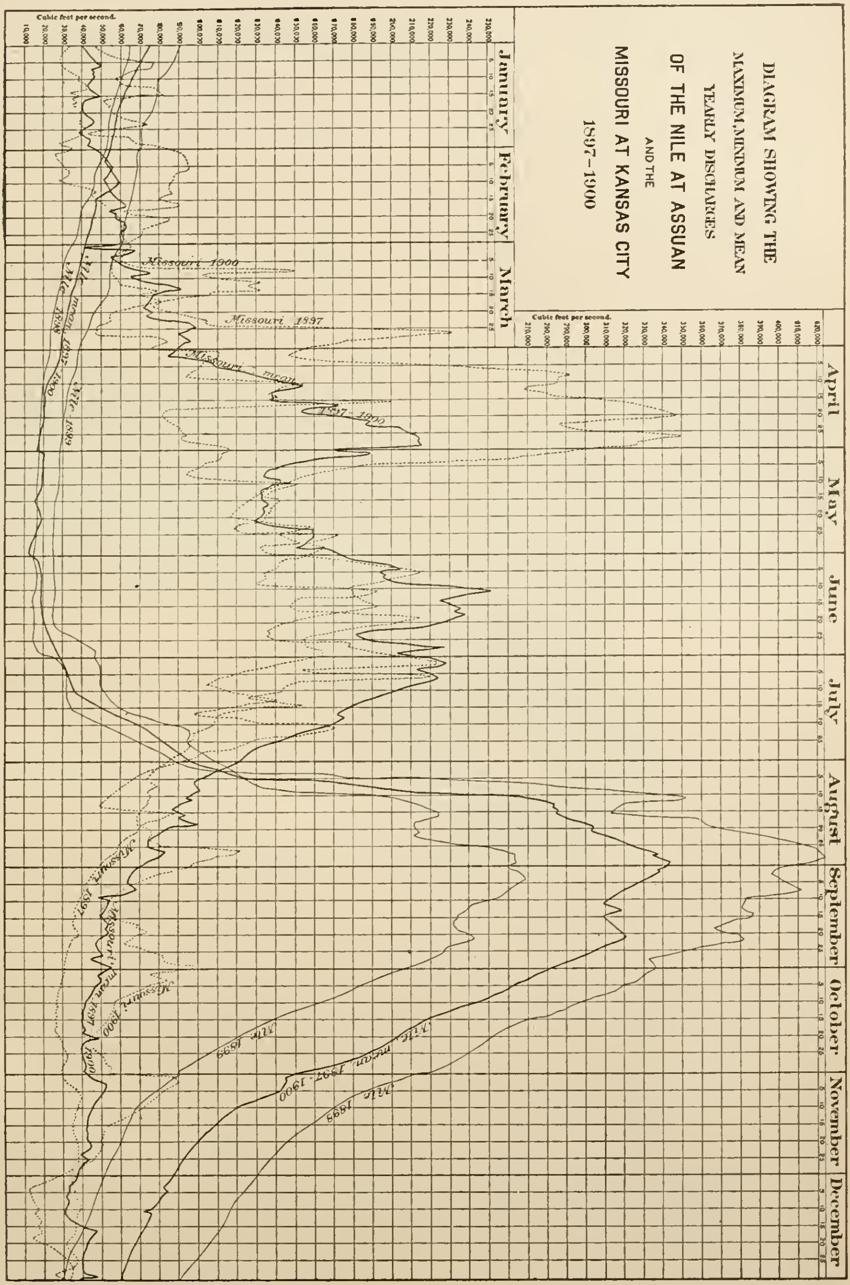


Fig. 2.—Diagram showing discharge of the Nile at Assuan and of the Missouri at Kansas City.

tributaries to the main stream and no local precipitation in Nubia or Egypt.

The ancient Egyptians worshipped the Nile and the sun. All benefits came from these two sources. The inscriptions on many of the temples show the Nile in different phases of its discharge, and many of the scenes pictured there represent the rulers or priests navigating the river. Unfortunately, the tourist seldom sees the Nile in flood. Instead of a gigantic river he sees a sluggish stream of muddy, uninviting water. Its channels are filled with many sand bars. Its banks may be protected by riprapping; they may be rocky or sandy to the water's edge, or supporting a luxurious growth of wheat, clover, or beans. As the river falls crops are planted wherever possible to the water's edge until extreme low-water level is reached. The tourist observes shadufs and other water-raising devices by thousands, but unless he travels otherwise than by boat he has but little opportunity to examine these curious devices for carrying water over the high banks of the Nile, nor does he see much of the land which is watered in this way. He often leaves Egypt without understanding why the Nile should be known as the Father of Rivers and one of the most remarkable in the world. To an American it looks like the Missouri below Omaha at low water. The similarity would be even more striking if the bluffs bordering the Missouri were barren sand hills instead of being covered with vegetation.

The low-water period of the Nile continues until the middle of July. The critical season is between the middle of May and the middle of July. The sun shines from a cloudless sky and the air is filled with dust. Land not perennially irrigated[a] is cracked with heat and thoroughly sun baked. Both man and beast suffer for water except where the Nile, the perennial canals, or wells can be easily reached. Even the branches of the Nile in the delta are practically dry in many places, the water all being diverted at the barrage or pumped from the channels of the river below this structure. During the first part of July all are anxiously awaiting the first appearance of high water. About the 12th or 15th of August the basins of Upper Egypt begin to receive water. The canals for perennial irrigation in both Upper and Lower Egypt are then running bank full and everyone is irrigating the crops so lately threatened with drought.

About the 1st of September the Nile is a mighty torrent, having increased from 12,000 cubic feet per second to 400,000 cubic feet per second or more. Upper Egypt, with the exception of the land perennially irrigated, is a lake dotted with island villages for thirty to forty-five days. After thirty days have expired people are anxious for signs of retreating waters and eagerly await reports from Assuan and other places. It is believed that if the water stands on the land more than forty days insects will be plentiful and crops will be partially destroyed. By prolonged high water the planting season is much delayed and the harvest extended into the hot spring months, which greatly reduces the yield. The basins, however, can not be drained until the Nile begins to fall. During all this time the levees must be watched and an army of men working without compensation is called out for this duty. About the 1st of October the flood is generally over and the basins begin to empty. This is not only a difficult operation in itself, but the volume of water turned back into the Nile causes high water on the lower reaches of the river and lengthens the period during which the banks have to be guarded. In the delta the Nile runs above the level of the surrounding agricultural lands and a breach of one of the embankments means an immediate overflow of the neighboring country.

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[a] Lands along deep canals which always carry water are irrigated throughout the year, hence the terms "perennially irrigated," "perennial irrigation," etc.

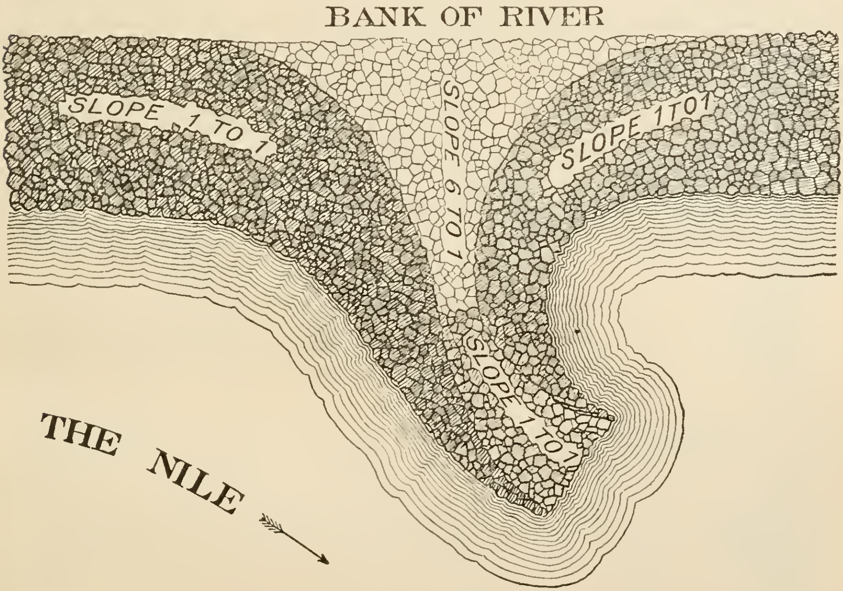

Fig. 3.—Spur to prevent erosion of river banks.

Changes take place in the channel of the Nile during each season of high water. Often the current will change, and where there had formerly been a gradual slope and considerable agricultural land a steep, caving bank will remain. The lowlands and the banks of the Nile which are farmed each year vary considerably in area from one season to another. The agricultural land adjacent to the river is perennially irrigated, and therefore highly productive. In addition, the Nile banks are lined with buildings and expensive pumping machinery. To protect the land and improvements the government must either build a masonry wall or reduce the slope and riprap it. It is quite common to put spurs in the banks some distance above the points threatened to throw the current farther out in the stream. This is often a dangerous expedient, as the current thus deflected may do considerable damage at other points. Fig. 3 shows one of these spurs constructed by the government.

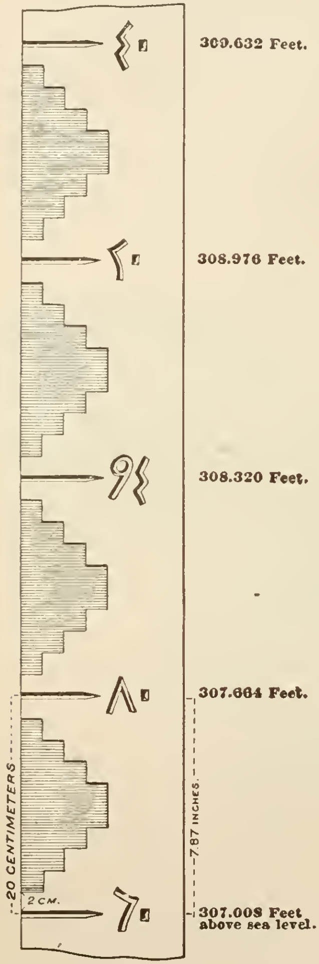

Fig. 4.—Nilometer on the Elphantine Island.

NILE GAGES.

Much has been written about the flow of the Nile, yet it has never been carefully measured until recently. Although Nile gages, now known as "nilometers," were established at an early date, the relation between the gage heights and the discharge was never determined until during the last half century. The measurements first made, even by persons qualified for such work, were rough and can be regarded as only approximate. The use of the current meter has finally permitted accurate gagings to be made, and it will doubtless not be long until enough of these have been taken to give value to the gage heights already recorded.

On many of the rocks along the Nile in Nubia extreme high-water levels have been recorded. Such marks were doubtless the earliest gages of the Nile. During the past few years some old gages have been discovered at Assiut and other points along the river. The most interesting and among the most ancient of the gages are on the island of Philae. The two which can be seen to-day are on the west side of the island. They consist of a narrow stairway leading by a short subterranean passage from the surface of the ground on the island to the river. The gages are placed on the walls of this passageway and are in sections of 3 or 4 feet each. The ancient gage is graduated in cubits or pics and kirats. On the Nile gage toward the south end of the island of Philae there are a number of different scales, the most modern one being graduated in meters and centimeters, similar to the gage on Elephantine Island, as shown in the accompanying cut (fig. 4).

Instead of taking the bed of the river as the zero of the scale, it is referred to mean sea level at Alexandria.[a] It is impossible, therefore, to tell the depth of the water by reading the scale. The gage on the south end of Elephantine Island is of the same character as those on the island of Philae. The modern gage is carefully constructed, being inscribed on pieces of white marble. The gages at Philae are the most reliable, as the channel of the river there is composed of granite, and from the records of a great many years it is found that the average heights of the river have varied but little. The gages on the Lower Nile are of little value in comparison, as the bed of the river is constantly changing.

By far the most celebrated of the gages on the Lower Nile is the one on the island of Rhoda. The graduations are on a pillar which stands in the center of a well, the bottom of which is connected with the Nile by a passage. This column is of stone, octagonal in cross section, and the well in which it stands is about 16 feet square. The nilometer is graduated in pics and kirats.

At the present time the irrigation engineers depend for their first news regarding the stage of the Nile on telegraphic reports from Khartum. The people, however, look to Assuan for their information and are scarcely satisfied until reports are received from that place. From approximate gagings made of the Nile at Assuan the writer has prepared a rating table, from which the yearly discharges of the river have been computed, as shown in figs. 2 and 3. These diagrams are trustworthy only in so far as the gagings are assumed to be correct.

The English engineers have established gauges at a number of points along the Nile above Assuan, among which are those at Khartum, Berber, Wady Halfa, and Lake Victoria. From the reports received from these gaging stations the engineers know approximately what kind of a flood to expect each year, and the irrigator is advised accordingly.

AGRICULTURAL SEASONS.

There are three agricultural seasons in Egypt. The land not receiving perrennial irrigation can take advantage of but one. This begins as early as the middle of October and ends with March. The crops grown then under the basin system are sown immediately after the subsidence of the flood, hence the time of planting depends upon when the fields become dry enough for the seed (Pl. IV). The lands in southern Egypt are generally ready for the seed about the beginning of November. In the Delta crops are often planted as late as the 20th of December. Wheat is the principal winter crop, although clover, barley, beans, and many other products are quite commonly raised. The ground is seldom plowed before the wheat is planted. The seed is scattered over the still moist soil by hand, and it is either tramped into the ground by the cattle or pressed in with a primitive wooden roller. Sometimes the ground is beaten with a piece of wood and the grain actually driven into it. The harvest in extreme upper Egypt begins in February and is in progress down the river until the middle of April. In upper Egypt the winter harvest is the most important of the year because a large part of the land there depends wholly upon the ancient system of flood irrigation.

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[a] In the same manner the height of a dam or other structure is usually given by referring to the actual elevation of its base and top above sea level.

The summer crops are grown between April and August (Pl. V). However, a great many crops are planted in April and May which are not harvested until the following fall or winter. Among these are cotton, sugar cane, and rice, the most valuable crops grown in Egypt. Rice is generally planted in May and is not harvested until the following November. During exceptionally dry seasons a different variety, which ripens in from seventy to one hundred days, is planted quite late in the summer. Owing to the short time required for its growth it is known as sebani rice, meaning seventy-day rice. Cotton is sown in April and picked in November or December. Sugar cane is planted about the same time, and harvested in the following January and February.

The third season has a length of about eighty days, running from August to October and sometimes until November. During this time considerable sorghum is raised, the stalks of which the natives eat. Corn is the chief crop grown, and is second only to wheat among Egyptian cereals in yield. It is probably the most valuable crop to the poorer classes. As soon as it ripens it is cut or pulled up by the roots and piled on the levees, where the stalks dry thoroughly and where the corn is husked. The corn on the ears is then piled on the ground where the earth is firm and the grain is beaten from the cob by heavy sticks in the hands of the farmers. (Pl. VI, fig. 1.) The corn is next ground or crushed and bread is made directly from it, or it is mixed with bean flour before being prepared for food. Wheat is thrashed by a method almost as crude. A sledge furnished with rollers carrying metal disks is pulled by oxen, which travel around a stack of wheat until the straw is thoroughly chopped and the grain is separated from it. (Pl. VI, fig. 2.) The whole mass is then tossed in the air and the wind blows away the lighter material while the grain falls to the ground. This latter process is very tedious, as the straw has to be handled many times before the grain is all separated and cleaned.

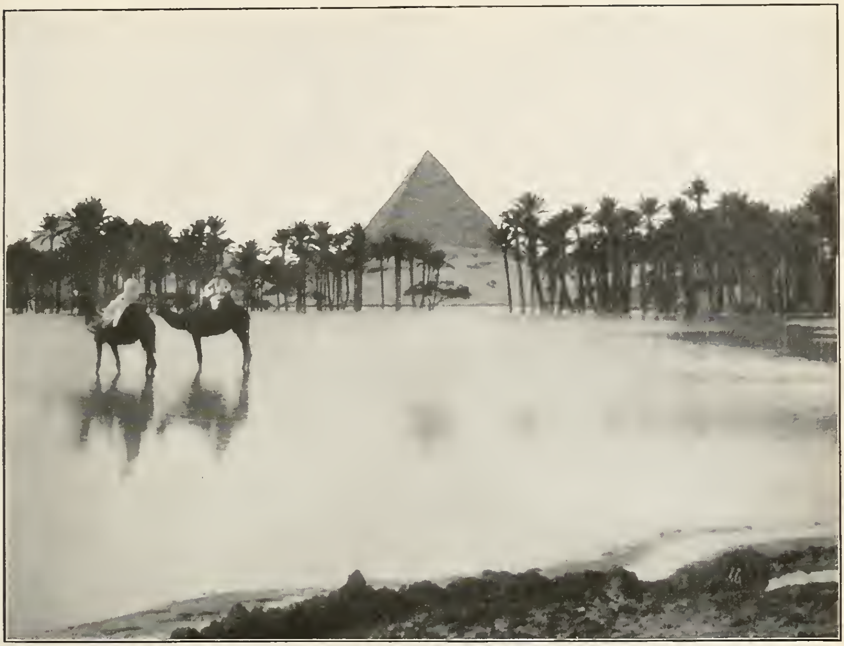


FIG. 1.—IRRIGATION BASIN NEAR PYRAMID OF GIZEH.

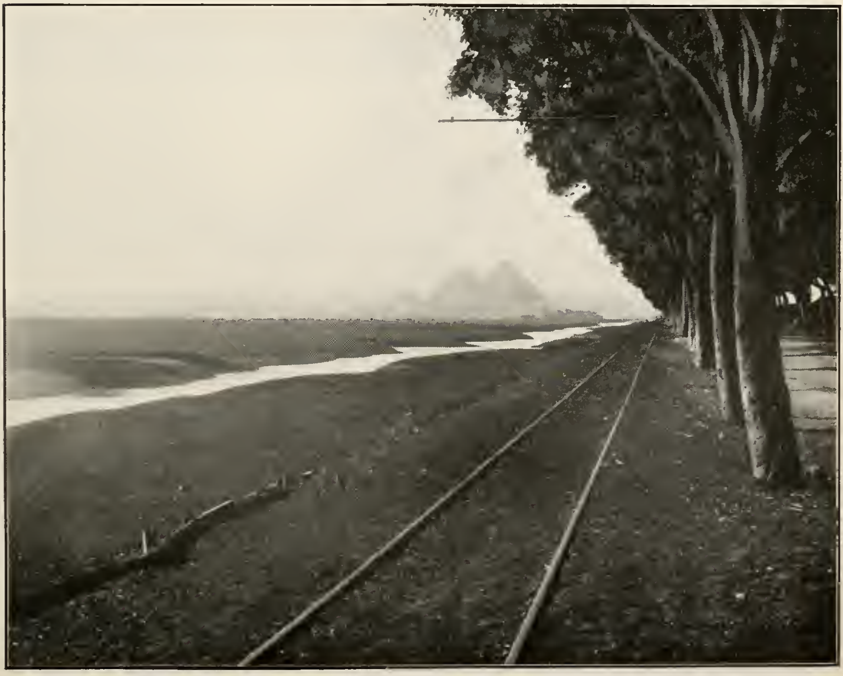


FIG. 2.—IRRIGATION BASIN WEST OF CAIRO, WATER RETURNING TO NILE IN CHANNEL.

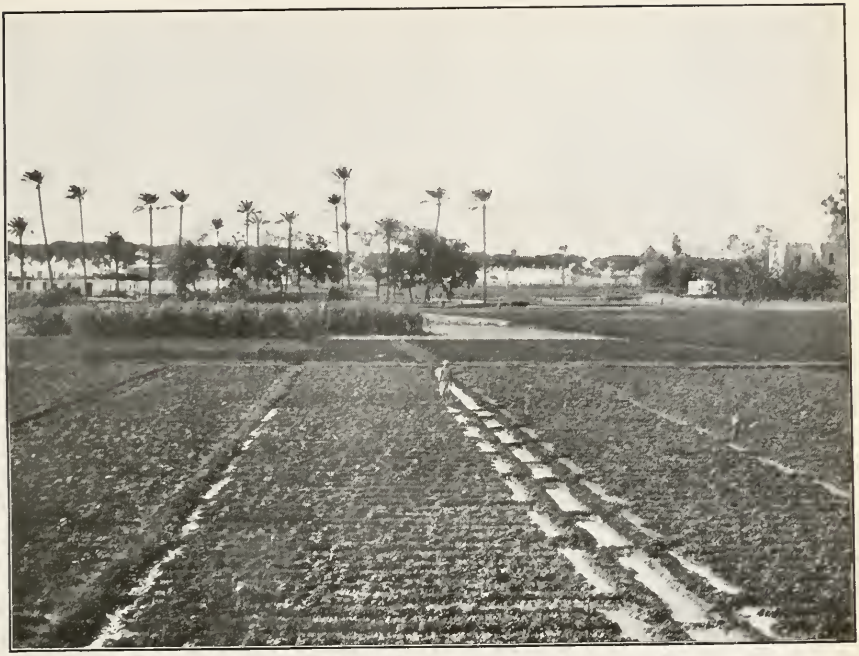


FIG. 1.—IRRIGATING STRAWBERRIES.

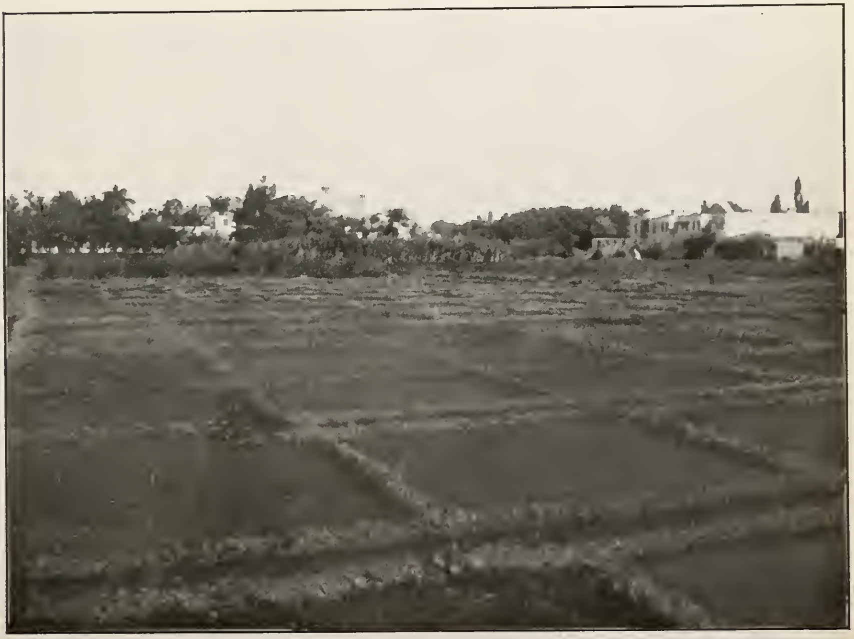


FIG. 2.—PERENNIAL IRRIGATION, WHEAT FIELD UNDER CHECK SYSTEM OF IRRIGATION.

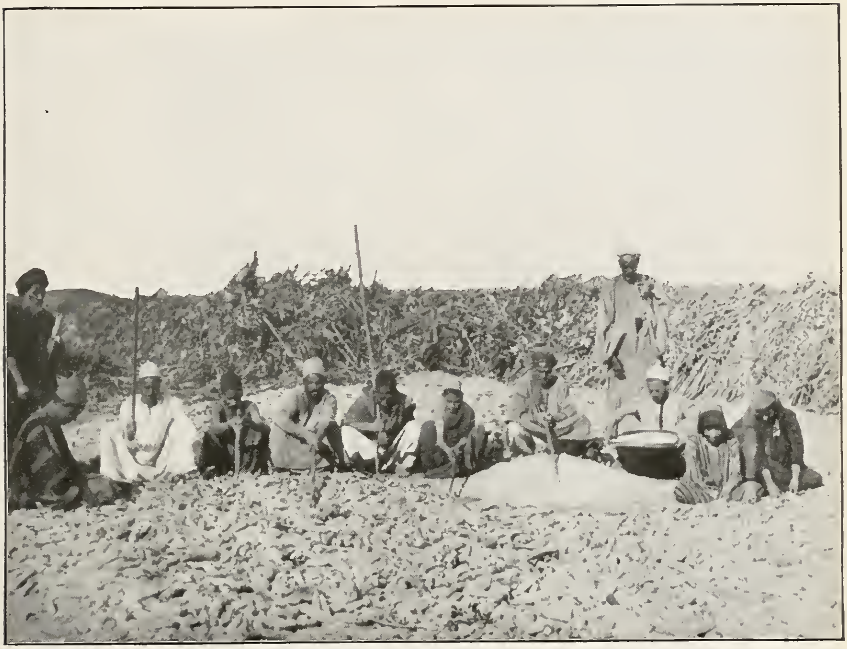


FIG. 1.—THRASHING INDIAN CORN.

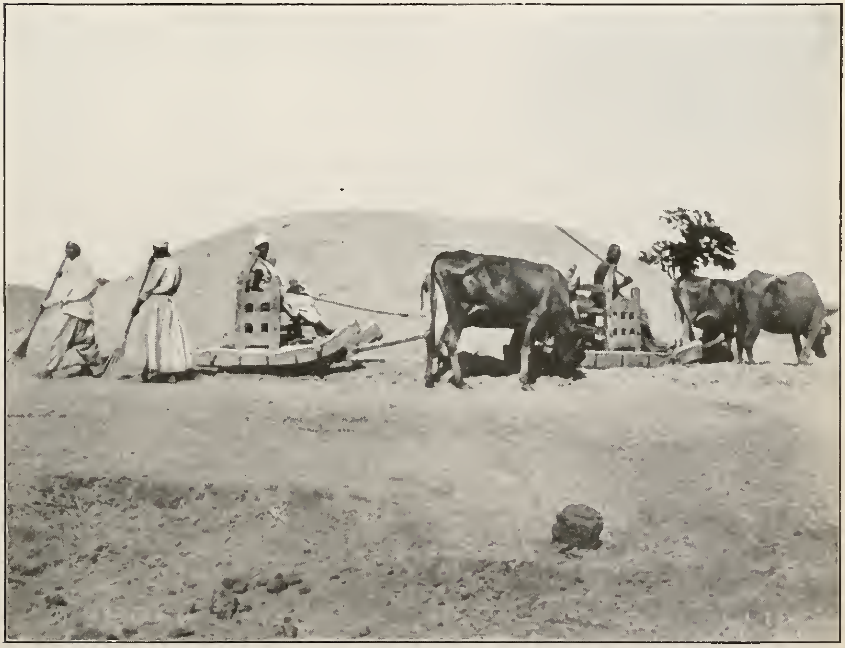
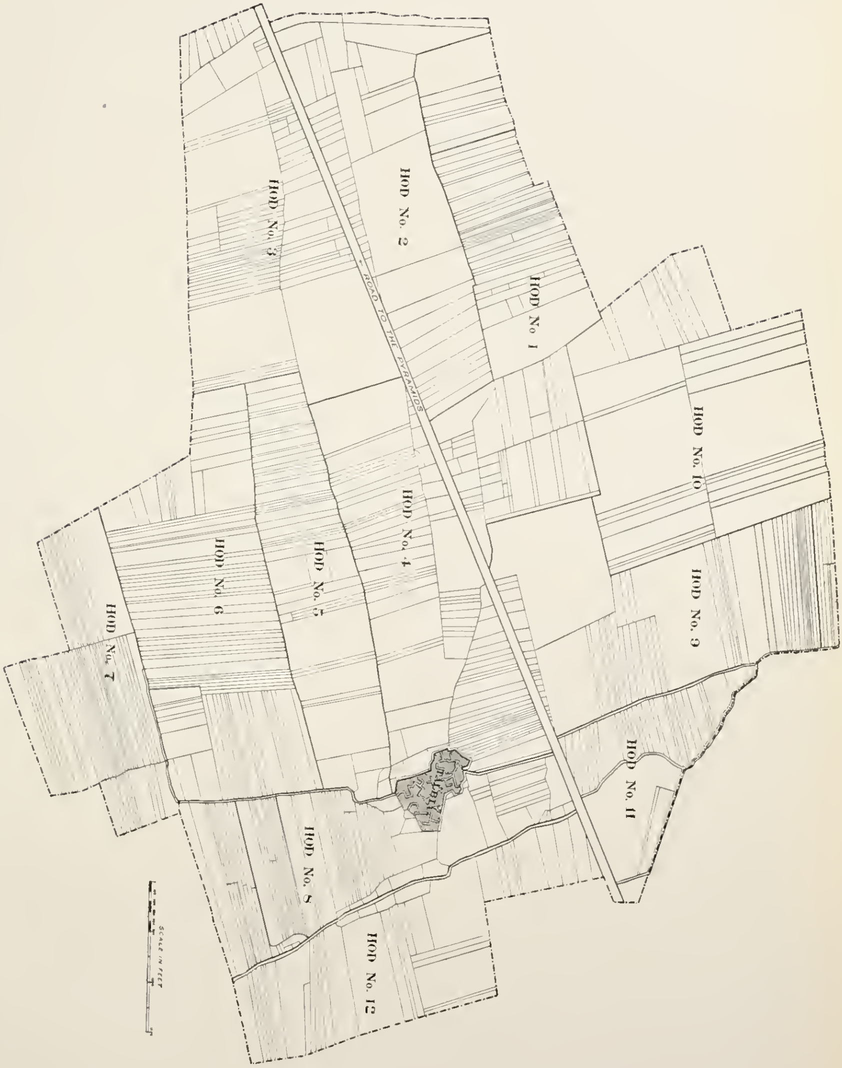


FIG. 2.—THRASHING WHEAT.

PLATE VII.


HOD No. 1
HOD No. 2
HOD No. 3
HOD No. 4
HOD No. 5
HOD No. 6
HOD No. 7
HOD No. 8
HOD No. 9
HOD No. 10
HOD No. 11
HOD No. 12
ROAD TO THE PYRAMIDS
TALBIA
SCALE IN FEET

PLAT OF THE VILLAGE OF TALBIA, SHOWING TOWN AND TRIBUTARY FARMS.

FARMS AND VILLAGES.

The term "village" as used in Egypt refers generally to an area of land surrounding and including a town. The farmers have their dwellings in the towns. In the portions of Egypt subject to inundation they are obliged to retreat to the towns during high water. A frontage on the river or other source of water supply is always desirable and these channels are generally boundary lines of farms, the dimensions of which are as unusual as the tools used in cultivating the ground. To enable the greatest number to enjoy the advantages of a water front the width dimension of the farm usually lies along the river or canal. Where water channels do not exist it has become the custom to establish a few lines by permanent monuments. These lines then become the end boundaries of the farm. When a small area is sold its length is the same as that of the original tract and its width is laid off along the lines fixed by permanent monuments. As the area owned or cultivated by each fellah is small, their farms are long and narrow. A square piece of land containing the same area could be worked to much greater advantage.

The accompanying map (Pl. VII) shows the subdivisions of the farming lands of the village of Talbia, near Cairo. The holdings are small in the neighborhood of this village and the land is quite productive. The areas of ten farms, selected more or less at random, ranged from 0.02 to 1.04 acres.

Any small district throughout which the productiveness and therefore the rate of taxation is unusually uniform is known as a hod. The farms of each hod are numbered independently. The official records therefore may refer to farm No. 10, hod No. 6, of the village of Talbia. The maps compiled from government surveys show the farms and hods with their numbers, permitting any particular farm to be identified. Fences are not provided along farm boundaries, as they would occupy too much land.

In the surveys for the finance ministry, villages are mapped independently. It is almost impossible to make up from these separate surveys a general map showing a number of villages, as the boundaries of the villages are irregular and discrepancies always occur in approximate work of this kind. A survey of the boundary between two villages defined by a canal or other water course may be made during the season of high water. At the time it may be impossible to locate the water channel accurately on the map. If the adjoining village be surveyed during low water, it is easy to see that maps made from the surveys would not fit when applied to each other. Outside of these surveys, the Government possesses little information regarding the topography of the country.

Under the French occupation some general surveys were made, but no monuments were established. The English engineers are making a survey of Egypt and are establishing monuments in some cases. It is doubtful whether these will have any great permanent value as they are not tied to guide meridians or standard parallels. The lack of monuments in the surveys of the villages makes it necessary for the farmers in the districts inundated to resurvey their lands after each subsidence of the water. A few permanent monuments may always be found in the villages and from these the rest of the land is laid out.

The work is repeated until a majority are satisfied that the land has been properly measured. It would cost the farmer only 5 or 10 cents per stone to establish permanent monuments at the corners of his farm, but so fixed has become the custom of remeasuring the land each year that it is preferred to a more convenient system.

English engineers in the survey department are handicapped not only by their inability to secure the best kind of assistance in the field, but by existing surveys recognized by the native farmer. His ancestors measured land to their satisfaction, and he is content to follow their example, not only in the surveys but in the computation of field notes. The Egyptian has a special formula for computing the area of land to which he adheres with a steadfastness which would be praiseworthy in a better cause. For instance, when a triangular piece of ground is to be surveyed, only the lengths of the sides are taken. To compute the area the lengths of two adjacent sides are added, the sum is divided by 2, and this quotient is multiplied by the length of the remaining side divided by 2. If the figure happens to be a quadrilateral, the two opposite sides are added together and divided by 2 and the quotient is multiplied by the two remaining sides added together and divided by 2. Putting the formula in figures and referring to the accompanying diagram, the inaccuracy of the method may be plainly seen (fig. 5).

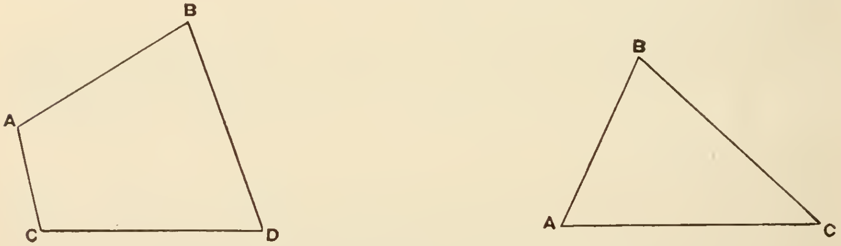


Fig. 5.—Diagram showing inaccuracy of land measurements.

$$\text{Area of triangle} = \frac{ab + bc}{2} \times \frac{ac}{2}$$

$$\text{Area of quadrilateral} = \frac{ab + cd}{2} \times \frac{ac + bd}{2}$$

The formula for the area of a triangle never gives accurate results. The formula for a quadrilateral is correct only when the figure is a rectangle.

A few years ago an investigation was made to determine the average size of the land holdings in Egypt. At the same time considerable information was gathered regarding the number of farms and as to whether the owners were natives or foreigners. It was found that foreigners owned 5,139 farms, having a total area of 233,838 acres. The average size of these farms was therefore 45.87 acres. There were 22,699 farms owned by natives who, having considerable influence, had secured titles to large areas under the conditions prevailing prior to the occupation of the English. These people held 1,420,187 acres, the average size of the holdings being 62.59 acres. There were 502,810 farms belonging to the peasantry. They owned 2,752,500 acres, making the average size of their holdings 5.47 acres. The total number of farms in Egypt was 530,548. The total cultivated area exclusive of state lands and the area administered by the Daira Sanieh was 4,406,525 acres. The average size of an Egyptian farm was therefore 8.3 acres. The total population of Egypt at the time the census was taken was 6,754,050, so that one person in twelve was a landowner, while 80 per cent of the landholders owned less than 10 acres each.

COST OF RAISING CROPS AND VALUE OF FARM PRODUCTS.

The cost of raising different crops, as well as the yield of the same, varies greatly throughout Egypt. Crops grown in the winter on lands employing the basin system of irrigation can be matured much cheaper than those grown under perennial irrigation where water must be lifted. In the best agricultural districts of Upper Egypt sugar cane is the most valuable crop. In preparing the ground for seed and sowing the same an outlay of about $7 per acre must be met. The seed costs from $10 to $12 per acre, irrigation about $10, cultivating and harvesting $14, making the total cost per acre amount to $40 or $45 per acre. If the land requires fertilizers the cost of these may make the yearly expense $2.50 higher. The yield of sugar cane averages about 32 tons per acre, which is worth $128. The net profit from an acre of sugar cane is, therefore, between $80 and $85 per acre. If the land is rented the tenant probably pays from one-third to one-half of the crop to the owner. The landowner pays between $5 and $10 in taxes each year on such land. The cost of raising cotton in Upper Egypt is about one-third as much as for raising sugar cane, while the net profit approximates $50 per acre, or about five-eighths as much. The cost of raising other crops runs from $1 to $6 per acre in Upper Egypt. The principal crops grown there in order of their importance are sugar cane, cotton, wheat, Indian corn, millet, vegetables, beans, and clover. Some fruit is grown, especially in the Fayum, where oranges, lemons, limes, olives, etc., are quite common.

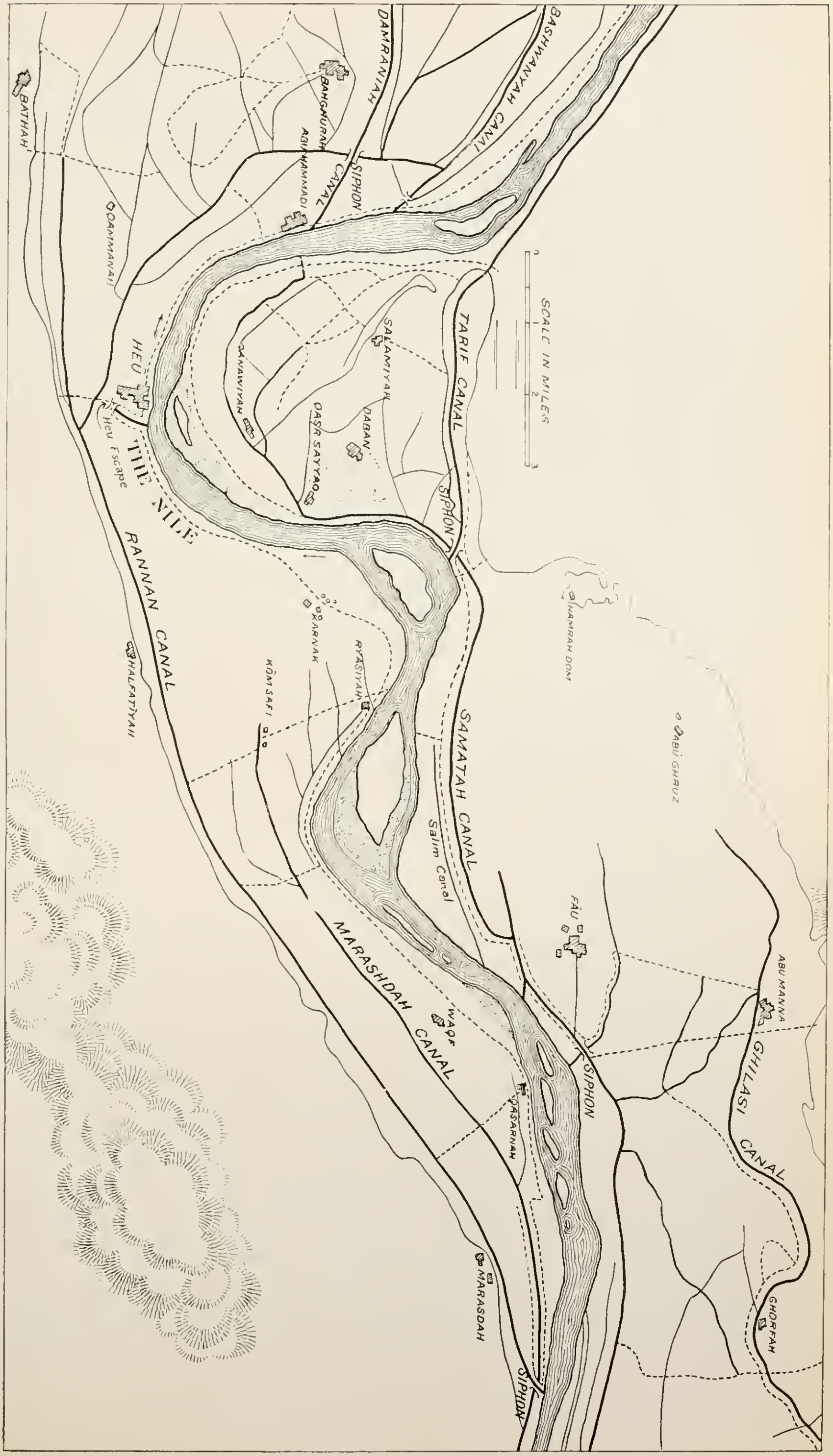
In the southern half of the delta sugar cane is grown principally for eating purposes. The cost of raising the cane there is about the same as in Upper Egypt, but the net profit derived from the ground is about twice as great. Fruits of different kinds are among the most profitable crops of this portion of Egypt. The date is grown extensively, and a special tax is levied on this fruit. When a tree is cut down another must be planted in its place. The government revenue from an acre devoted to raising dates runs from $10 to $45 per acre. The cost of cultivating the ground approximates $50 per acre, while the net profit is about $150 per acre. Considerable land is devoted to the growing of different vegetables. The cost of raising vegetables averages about $15 per acre, while the net profit from the ground is about $55 per acre.

While some cotton is grown in the northern half of the delta, this portion of Egypt must be regarded as essentially a rice district. The net profit from the cotton fields is about $25 per acre, while rice pays from $6 to $18 per acre only. Much of the rice grown in this portion of Egypt is planted on ground which is being reclaimed and put in condition for the production of more valuable crops. Indian corn, barley, wheat, and clover are the other crops grown in the northern portion of the delta. Some fruit is produced in the vicinity of the towns and villages.

DEVELOPMENT OF EGYPTIAN IRRIGATION.

Originally all of the agricultural lands along the Nile, except a narrow strip, depended upon the flood of the river for irrigation. But one crop could be grown each year, and this in the winter time. During the remainder of the year the land remained fallow. Most of the large canals were built during the twelfth dynasty (2200–1600 B. C.). Levees were built along the Nile and the farming land was divided into basins, which were filled with water from canals when the river rose to a marked place at the head of the El Khalig Canal at Cairo. As soon as this height was reached word was sent throughout Egypt; the temporary earthen embankments at the heads of the canals were then broken, and the water ran to the basins. If the Nile failed to rise sufficiently high to furnish water for the basins, considerable suffering resulted. If the river was too high, embankments would break, levees would be washed away, and widespread desolation would result. It was not only necessary to fill the basins with water, but the water had to be red with silt from the mountains and plains of Abyssinia. If the land failed to receive the deposit of red mud, the yield would be reduced. Emptying the basins was even more difficult than filling them. The lower basins had to be emptied first, or, if good

PLATE VIII.


BATHAH
BAHGHURAH
ABU HAMMADI
DAMRANIAH
SIPHON
CANAL
BASHWANYAH CANAL
DAMMANAH
HEU
Heu Escape
THE NILE
RANNAN CANAL
HALFATIYAH
ZANAWIYAH
SALAMIYAH
DABAN
QASR SAYYAD
TARIF CANAL
SIPHON
SCALE IN MILES
0
1
2
3
KARNAK
RYASIYAH
KOM SAFI
HAMRAH DOM
ABU GHRUZ
SAMATAH CANAL
Salim Canal
FAU
ABU MANNA
GHILASI CANAL
SIPHON
MARASHDAH CANAL
WAQF
DASARNAH
MARASDAH
GHORFAH
SIPHON

MAP SHOWING IRRIGATION WORKS IN A PORTION OF THE PROVINCE OF KENEH.

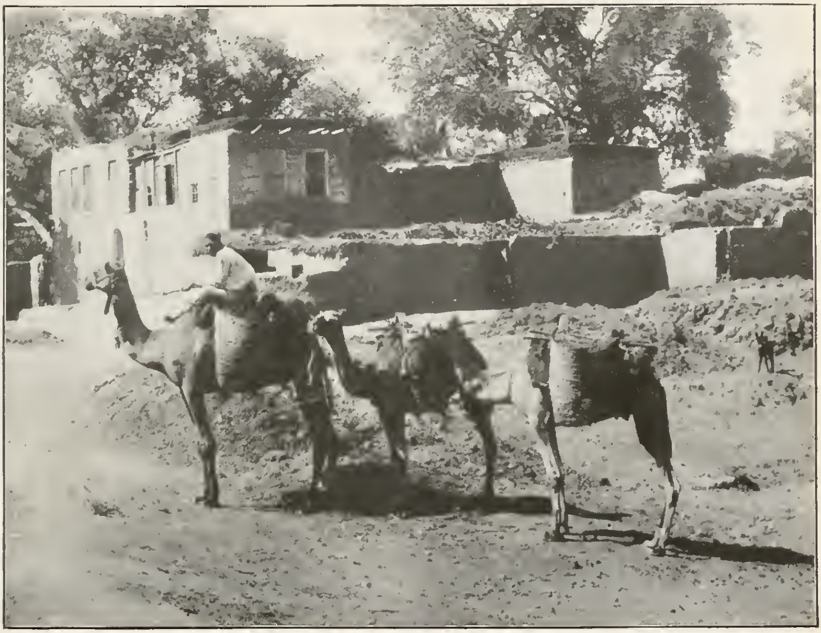


FIG. 1.—CAMELS CARRYING RUINS OF VILLAGE TO BE USED FOR FERTILIZER.

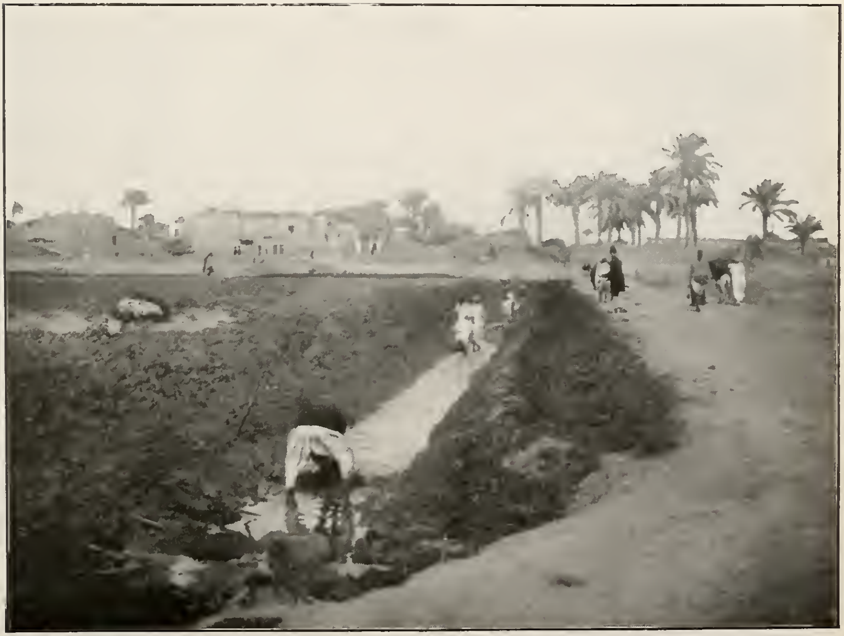


FIG. 2.—CLEANING A SMALL CANAL.

regulators were provided between them, the water from all could be run at once. If one of the embankments of an upper basin broke, it meant devastation to everything below. The basins could not be emptied until the Nile began to recede, and there was nearly as much danger in having the flood continue too long as in not having a sufficient supply of water. This system has survived to the present time. While the basins first laid out were crude, they have developed after many years of experience into well-regulated systems. Expensive regulators have been constructed and canals have been made large enough to carry water to supply the land they were intended to serve. The escapes into the Nile have been perfected. The land near the Nile is above the level of the adjoining farms (fig. 6). For this reason it is difficult to fill the basins near the Nile embankments. The grade of the Nile varies from one-half to one-third of a foot per mile. Owing to this slight fall the canals have to be quite large, because their grade must be less than that of the river. Even under the most favorable conditions they can not gain more than a small fraction of a foot per mile over the river. When a canal reaches the edge of the desert, or, in other words, covers all of the arable land except the Nile berm, it follows the desert until a new canal is taken out, when the first canal siphons under the new one and covers the high land along the river. The second canal proceeds in the same way and siphons under the third. By this system canals can be made to serve the entire area of agricultural land.

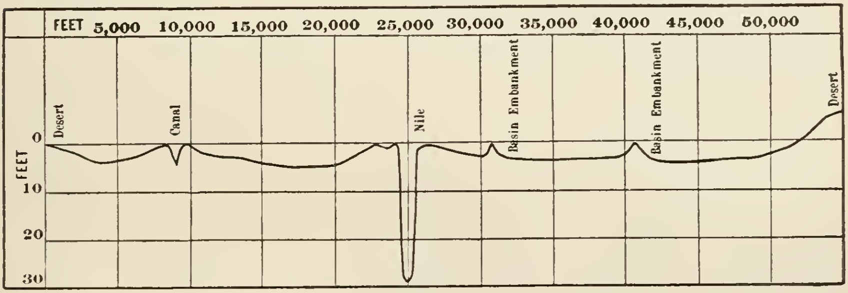


Fig. 6.—Typical cross section of the Nile Valley.

Pl. VIII shows a portion of the Nile Valley in the province of Keneh where the river has a general course from east to west. The strip of irrigated land, bounded by right lines, is in no place over 7 miles wide. It will be seen that the Rannan Canal heads at the right, on the south bank of the river, and that the Marashdah Canal siphons under it just below the point of diversion. The latter canal is on a higher line at their intersection and waters the elevated lands along the berm of the Nile for 12 miles below the siphon. The Rannan Canal continues westerly and soon covers all the land to the border of the desert. Just before it reaches the Heu Escape, which was built to empty the basins above the south side of the river, it divides, one branch serving the high lands along the desert and the other furnishing water to the basins near the Nile. The basin boundaries are shown by dotted lines. The canal and basin system on the north side of the river are also shown. There are small areas here and there in Upper Egypt which are irrigated from wells, but the larger part of the land is still flooded by the Nile and enriched by its sediment, as it has been for thousands of years past.

But this ancient system of irrigation has one great drawback—but one crop can be raised each year, while all other conditions, except the water supply, favor the raising of several crops. Recognizing this, Mohammed Ali in 1837 began reforms looking to the supplying of water to crops during the whole year. The great barrage at the head of the delta was begun in 1843, as a part of the plans for perennial irrigation. The first perennial canals were in the delta and the Fayum, but the system is being gradually extended to the south, the country between Cairo and Assiut being in a state of transition, and the recent great works at Assuan and Assiut being for the purpose of increasing the area supplied with water throughout the year.

The returns from the soil have been greatly increased by the adoption of perennial irrigation. However, this system is accompanied with certain drawbacks. Only by the old flood-irrigation system can the land receive any considerable amount of rich Nile silt, and when two or three crops per year are taken from the ground the soil deteriorates quite rapidly. Artificial fertilizers are necessary, and these are expensive in Egypt. The principal supply of fertilizer at present is from the ruins of old towns and villages. This is simply the Nile deposit which has been used in times past in the manufacture of brick for the construction of houses, impregnated with more or less fertilizing matter derived from the village wastes. Long lines of camels may be seen carrying this material to the farms. (Pl. IX, fig. 1.) Sometimes it is to be transported 10 or 15 miles or farther, each camel carrying about 600 pounds, distributed between two wicker panniers thrown across his back.

THE CANALS OF THE NILE VALLEY.

As has just been pointed out, there are at the present time two kinds of canals in Egypt. First, the perennial canals of the delta, which date from the time of Mohammed Ali; the Ibraimia canal, and the canals of the Fayum, built like those in the United States, with the idea of receiving water throughout the year or whenever crops need irrigation. The water of these canals generally runs below the level of the irrigated lands. Second, the flood canals, for filling the basins in Upper Egypt, which leave the river on a much higher level relative to its bed.

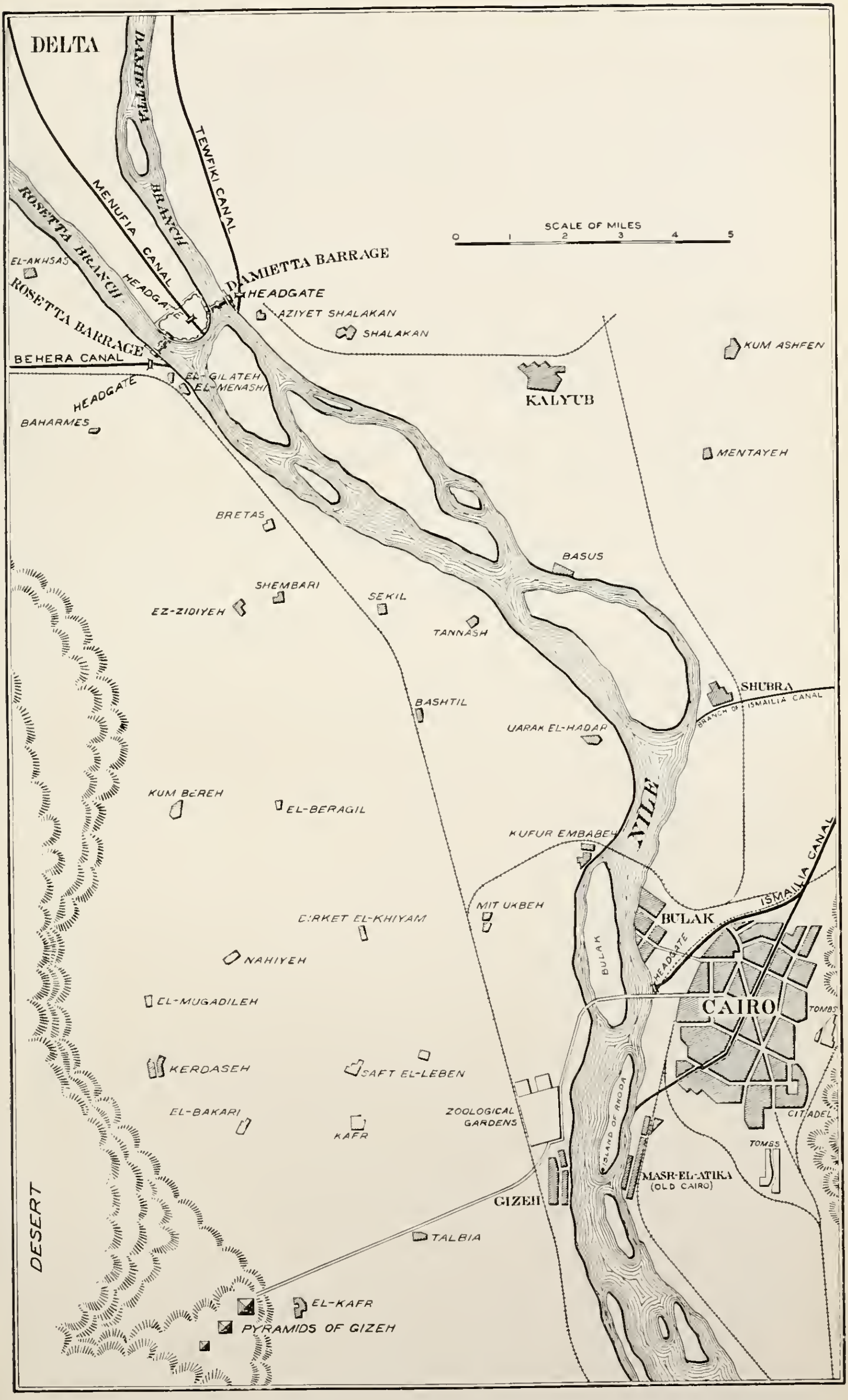
In the province of Assuan there are two canals on the left and four on the right bank of the river. These supply all the basins in that province during the flood season. The only area watered throughout the year is a narrow strip bordering the Nile and other water courses carrying a supply at all times. In the province of Keneh there are 8 canals taking water from the west bank of the river and 13 diverting water from the east bank. In the province of Girgeh 11 canals divert water from the left and 5 from the right bank.

Among those on the left bank is the great Sohagia Canal, one of the oldest water channels in Egypt. It supplies 340,000 acres of land. At its lower extremity the Yusef Canal begins, being a continuation of the Sohagia. So ancient are these channels that they have lost much of their resemblance to the canals of to-day and are now considered natural channels. They are very tortuous, and run at but slightly higher levels than the Nile. At its head the Sohagia is 230 feet wide on the bottom, 278 feet wide on top, and carries a maximum of 18 feet of water in depth. Its discharge is about 15,000 cubic feet per second. The canal is separated by embankments from the first basins it supplies. In the basins farther north the canal embankments are omitted. Here the canal is not a boundary line between basins, but flows through each. The length of the canal is about 60 miles. Just below its point of diversion from the river an immense masonry head gate has been erected. It is many times too large for the volume of water carried by the canal, and it would look much more in keeping with the surroundings if the canal were two or three times larger. The head gate contains 214 archways, each of which is nearly 10 feet wide. The foundation, which rests upon sand and gravel mixed with Nile mud, is 131 feet wide and 6½ feet thick. The superstructure is of brick, except the corners and other exposed parts, which are of stone. The piers are 6½ feet thick, and are about 20 feet high from the foundation to the springing line of the archways. The discharge is regulated by raising or lowering flashboards by means of a winch carried on a car running along the top of the structure. The basins filled by the canal are emptied at an escape not far from Assiut. Until recently they were drained by simply making a cut in the basin dike, permitting the water to flow back into the Nile. This was a very dangerous and destructive practice and has been reformed by the installation of a masonry escape.

In the province of Assiut two canals divert water from the left and eight from the right bank of the river. On the left bank there are also six laterals of the Ibraimia Canal. The Yusef Canal is now supplied by the Ibraimia at the town of Dirut, 54 miles north of Assiut. The Ibraimia Canal was never supplied with a head gate until recently, when the construction of the Assiut dam made it necessary that the discharge of the canal be controlled at Assiut, where immense masonry regulators and division gates have been put in. At Dirut there is a wasteway in the canal, through which the surplus water can flow back into the Nile. Just below the wasteway the division gates are located, and at this point the Yusef and two less important canals begin. The length of the Ibraimia Canal from Dirut to its lower terminus is about 130 miles. It flows almost parallel to the Nile, and in no place is it over 2 or 3 miles from the river. At Dirut the width of the canal on the bottom is about 65 feet, and the slopes of its banks are 2 horizontal to 1 vertical. The depth of water in the canal when full is about 30 feet. The water supplied to the Ibraimia Canal at Assiut serves to irrigate over 1,000,000 acres of land. About 600,000 acres of this is still irrigated under the ancient basin system.

The Yusef Canal supplies a number of basins along its course, but its principal duty is to furnish the Fayum province with water for perennial irrigation. The cross-section dimensions of this canal are very irregular. It averages about 175 feet in width on the bottom and has a depth of about 20 feet. There are levees on each side, however, which enable it to carry 30 feet of water at high Nile. During May and June it carries about 600 cubic feet of water per second. During high Nile the discharge is about 30,000 cubic feet per second. During low water summer cultivation is prohibited along the canal except in the Fayum province. The entrance to this province is between two desert plateaus, and the low gap is closed by a dike which completely separates the province from the Nile Valley proper. The Yusef Canal crosses this dike on a masonry structure composed of three arches. The Fayum province was formerly cultivated as the valley of the Nile had always been, but perennial irrigation is practiced at the present time, owing to the increased supply of water furnished by the canal. At the town of Medinet the canal separates into many smaller ditches, and a large part of the province is watered by these. About 250,000 acres are cultivated in the province. The slope of the land in the Fayum is greater than in any other farming district of Egypt. All the land in the province drains into Lake Kerun, which is 130 feet below the level of the Mediterranean.

In the province of Minieh three canals divert water from the right bank of the river. The three canals on the left bank are laterals of the Ibraimia Canal. These are quite important among the distributing works of the province. In the province of Benisouef six canals take water from the left and two from the right bank of the river. There is one important branch of the Ibraimia Canal in this province. In the province of Gizeh three canals take water from the left and one from the right bank of the river. Below Cairo there are many canals (Pls. X and XXIV). The principal ones are those leaving the Nile at the barrage and the Ismailia Canal, which diverts water from the river at Cairo.


DELTA
DAMIETTA BRANCH
TEWFIKI CANAL
MENUFIA CANAL
ROSETTA BRANCH
HEADGATE
EL-AKHSAS
ROSETTA BARRAGE
DAMIETTA BARRAGE
HEADGATE
AZIYET SHALAKAN
SHALAKAN
SCALE OF MILES
0 1 2 3 4 5
KUM ASHFEN
BEHERA CANAL
EL-GILATEH
EL-MENASHI
HEADGATE
KALYUB
BAHARMES
MENTAYEH
BRETAS
BASUS
SHEMBARI
SEKIL
EZ-ZIDIYEH
TANNASH
SHUBRA
BRANCH OF ISMAILIA CANAL
BASHTIL
UARAK EL-HADAR
NILE
KUM BEREH
EL-BERAGIL
KUFUR EMBABEH
ISMAILIA CANAL
MIT UKBEH
BULAK
BIRKET EL-KHIYAM
BULAK
HEADGATE
NAHIYEH
CAIRO
TOMBS
EL-MUGADILEH
KERDASEH
SAFT EL-LEBEN
ISLAND OF RHODA
ZOOLOGICAL GARDENS
CITADEL
EL-BAKARI
KAFR
TOMBS
MASR-EL-ATIKA
(OLD CAIRO)
GIZEH
DESERT
TALBIA
EL-KAFR
PYRAMIDS OF GIZEH

Map of the Nile Valley from Cairo to the Delta, Showing the Location of the Barrages and the Head Works of the Principal Canals.

The Ismailia Canal deserves special mention because it was constructed wholly by contract and in one piece. The Egyptian Government entered into an agreement with the Suez Canal Company to construct a navigable waterway from the Nile to some point on the Suez Canal. The canal was not only to be navigable, but was to be capable of furnishing fresh water to the towns along the main canal and the branch beginning at Ismailia and running parallel with the Suez Canal to the town of Suez. In addition, the canal was to supply water for the irrigation of a considerable area ceded by the government to the company. The contract stipulated that the canal should be so constructed as to contain 8 feet of water in depth during flood season of the Nile, 6½ feet at mean discharge, and 3¼ feet at low water. The canal has two head gates, the older one being in the city of Cairo. The second head gate is about 4½ miles north of Cairo, from which point a branch canal 2½ miles long connects with the main channel 5½ miles northeast of Cairo. For some distance the canal runs northeasterly along the edge of the desert, after which it turns to the east through a gap in the desert hills and continues to the town of Ismailia. For some 40 miles from Cairo it runs above the level of the surrounding country, and the water is confined between two parallel embankments. This has resulted in considerable seepage, which has destroyed large areas adjoining the canal. Some work has been done toward draining a portion of this country. Just before reaching Ismailia a branch of the canal takes off to the south and terminates at the town of Suez. In digging the canal some traces of an ancient channel leading in the same direction were discovered. Historical accounts of an older canal have been found. About 600 B. C., King Nekos began the construction of a navigation channel running between the east arm of the Nile and the Red Sea. The channel was never finished, although 120,000 natives employed upon it lost their lives in the undertaking.

The length of the Ismailia Canal from Cairo to Lake Timsah, near the town of Ismailia, is about 80 miles. The length of the branch leading south from Ismailia to Suez is about 53 miles. The bottom width of the main canal is about 40 feet. The slopes are 3 to 1. The bottom width of the branch canal leading to Suez is only about 25 feet, but the channel was not well excavated and the width is not uniform. In places it does not exceed 16 feet. Many important masonry structures are found throughout the length of the canal. Swing bridges are numerous, and substantial head gates and regulators are found wherever the discharge of the canal has to be changed. Owing to the depth to which the canal has been dug, and the necessity for keeping it cleaned out so that it will carry sufficient water for navigation during low stages of the Nile, large quantities of silt have to be removed each year. Formerly this deposit frequently amounted to 350,000 cubic yards each season. It has been reduced to about 160,000 cubic yards by partially closing the head gates of the main canal during high water and supplying it through the smaller canal already referred to, diverting water 4½ miles north of Cairo. Considerable work is required each year at the head gate of the supply canal. It is over a quarter of a mile from the bank of the river. The channel leading to this head gate fills with back water from the river during high Nile and immense quantities of mud are deposited.

Many of the canals in the delta are ancient river channels. Those taking water from the Nile at the barrage are artificial. Among these latter is the Manufia Canal (frontispiece), which is one of the most celebrated in Egypt. It furnishes water for the irrigation of nearly all the land in the delta lying between the two branches of the Nile. The head gate of the canal is similar in design to the barrage itself. (Pl. XI, fig. 2.) A lock has been provided at the head gate, and the canal furnishes an important waterway for the internal commerce of the delta. The canal is from 160 to 175 feet wide on the bottom, and at high water carries nearly 30 feet of water in depth. Its summer discharge is nearly 4,000 cubic feet per second.

The Tewfiki Canal diverts water from the Damietta branch of the Nile at the eastern extremity of the barrage. It was begun many years ago, but was not finished until after the occupation by the English. It furnishes water for a large area lying east of the Damietta branch, and its construction has added greatly to the value of this region through the introduction of perennial irrigation. The Béhèra Canal leaves the Rosetta branch of the Nile at the western extremity of the barrage. It is about 60 feet wide on the bottom, with slopes of 2 to 1. It runs for a considerable distance along the margin of the desert, hence receives large volumes of sand which, with the silt deposited during high Nile, have to be cleaned from the channel each year. Until recently nearly 1,000,000 cubic yards had to be removed annually, and, in spite of the enormous amount of work performed, the canal carried less than 600 cubic feet of water per second. The Béhèra Canal is about 25 miles long. At its lower extremity the Katatbeh Canal begins. It has about the same dimensions as the Béhèra Canal. It supplies all the smaller canals to the north and west. The surplus water from the drainage of the land it serves flows into Lake Mareotis. The Mahmoudia Canal begins 34 miles from the barrage of the Rosetta branch of the Nile. This canal runs for about 45 miles to the northwest and ends at Alexandria. It supplies fresh water for that city besides furnishing water for irrigating a large area. The Mahmoudia Canal has for a long time been supplied with water by means of immense pumps located at Atfeh. Since the repair of the barrage the pumps of Katatbeh have been removed to Mex, which station keeps down the level of Lake Mareotis.

CONSTRUCTION AND MAINTENANCE OF CANALS AND LEVEES.

Nearly all large public works in Egypt have been constructed by the corvée (See p. 74.) The system was much abused when the English began their occupation in 1882. As soon as possible some relief was afforded the corvée by direct appropriations, under which a part of those employed on public works were paid for their labor at a price fixed by the government. These appropriations were increased until in 1889 all work of cleaning canals was paid for. Since that time the corvée has been called out only for the protection of the Nile levees during flood season, a period of from sixty to ninety days. While thousands of men are thus compelled to give their time without compensation, it is for the public benefit, and the length of their service is short, seldom longer than fifteen or twenty days. But little complaint is now heard, as the work is necessary and the service must be compulsory to be efficient. The time will doubtless come when this service will also be paid for.

The manner in which the native digs or cleans canals is interesting. His one tool, which resembles a hoe, is illustrated in the accompanying sketch (fig. 7). The engineers measure the material which is to be removed, and each man or party excavates a certain section containing a known yardage. (Pl. III). Frequently a number of men will work together, one using a hoe and the others carrying baskets holding about half a cubic foot of earth. The earth is loosened and the baskets filled by the use of the hoe. Where dry sand is encountered the hands are used to fill these baskets. Children are often seen carrying the baskets, but the hoe is nearly always handled by the men. Under this method of excavation canal sections are made smoother and more regular than under the methods commonly employed in the United States. Steps of earth are left in the banks, enabling those carrying material to walk with considerable ease. On the smaller canals and laterals the earth is often loosened with the hoe and thrown out by hand. Sometimes it is necessary to clean these when a foot or more of water is standing in them, in which case the material, if plastic, can be easily handled. Where the banks are higher, the earth may be thrown by a man in the bottom of the ditch to another on the bank, and by him pitched out.

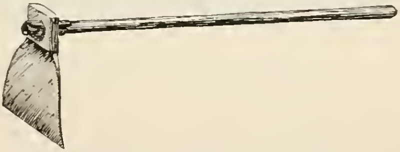


FIG. 7.—Hoe used by native farmer.

Near Medinet el Fayum a photograph was secured of a number of natives cleaning a small ditch. (Pl. IX, fig. 2.) The soil was a black loam, thoroughly saturated with water. The men loosened the material with their hoes where necessary and removed it by hand. The material was sufficiently plastic so that each handful retained its form after being deposited. After a day or so in the sun these become dry and hard and are of no value in the bank of the ditch. On an average one man can excavate about 3 cubic yards of earth a day if the lift be not too great. For this service he is paid about 15 cents, which admits of the cleaning of a canal at the rate of 5 cents per cubic yard. This is the cheapest method of performing the work under Egyptian conditions. It costs about 15 cents per cubic yard to clean a canal with a steam dredge, owing to the higher price of labor necessary to run the machine and to the cost of coal. The large canals are usually cleaned after the water has been drained out and they have dried. When it is impossible to drain them completely the unpleasant features of the work are greatly increased.

WATER-RAISING DEVICES.

As has been before stated, most of the water for irrigation, except in that portion of Egypt which still retains the ancient basin system, flows below the level of the land to be irrigated, the necessary lift varying with the stage of the river. The native machinery for lifting water has been designed to work regardless of this fluctuation. While none of this machinery is efficient, it serves for the irrigation of a large area. The shaduf and the sakiyeh are used when the fluctuation is great or where the lift is over 5 or 6 feet. Both are of ancient origin. They can be applied to almost any lift, are easy to construct, and do not require many repairs.

But little is known regarding the lifting machines used by the ancient Egyptians. Probably the first devices invented by them were much more primitive and not as efficient as those used to-day. Many of these machines have become obsolete because it was found that they did not have as wide a range of application as have the devices now generally employed. It may be that the scarcity of the material from which the lifting devices were built has largely affected the change in design.

THE SHADUF.

The shaduf consists essentially of two vertical supports about 5 feet apart connected by a horizontal crosspiece some 5 feet from the ground, a pole hung on this crosspiece like a well sweep, and a bucket suspended from this pole. In many places the uprights supporting the crosspiece are made of small sheaves of cornstalks stiffened with a coat of Nile mud. Sometimes the mud is used alone. The pole is hung 6 inches beneath this crosspiece, as shown in Pl. XII. This pole is not balanced, but is supplied with a counterweight on the shorter end, which extends away from the water. Suspended from the other end is a long pole to which a bucket is attached. This bucket is usually made of leather stiffened near the top by a wooden hoop. Its capacity

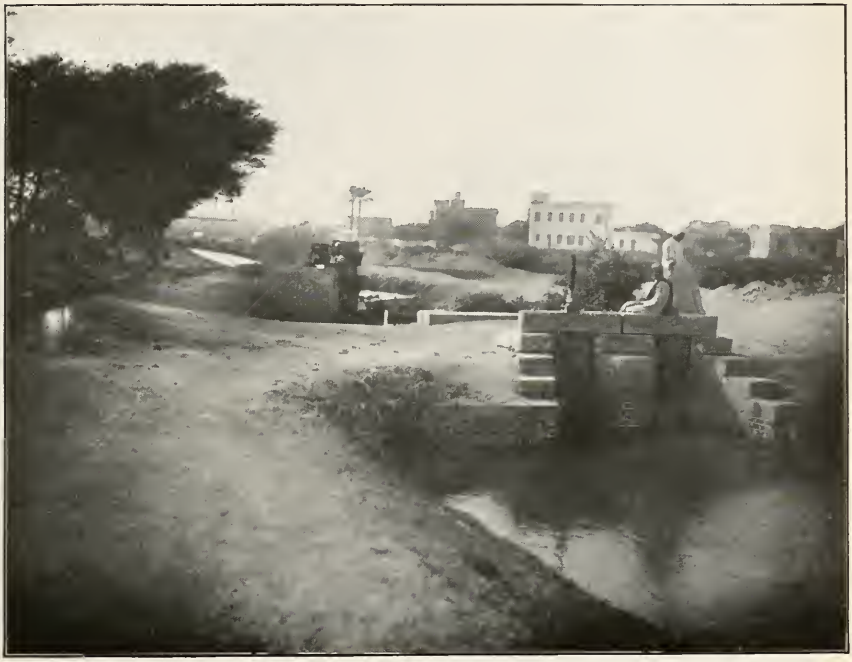


FIG. 1.—LATERAL HEAD GATE.

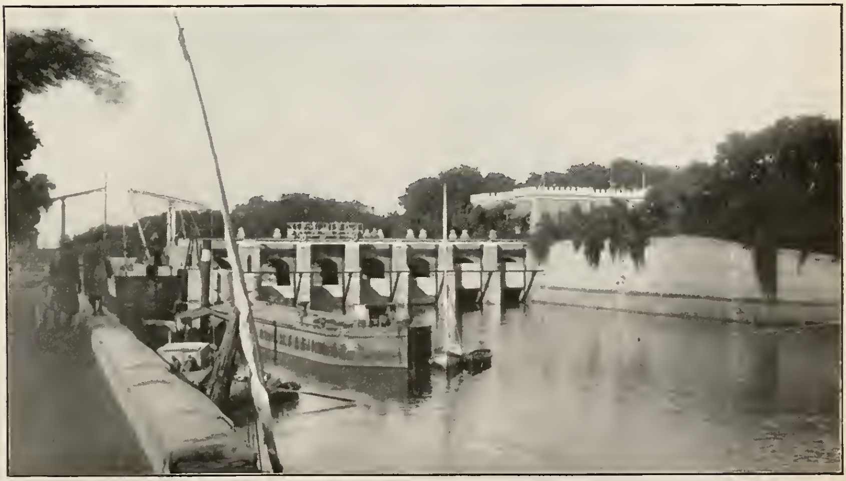
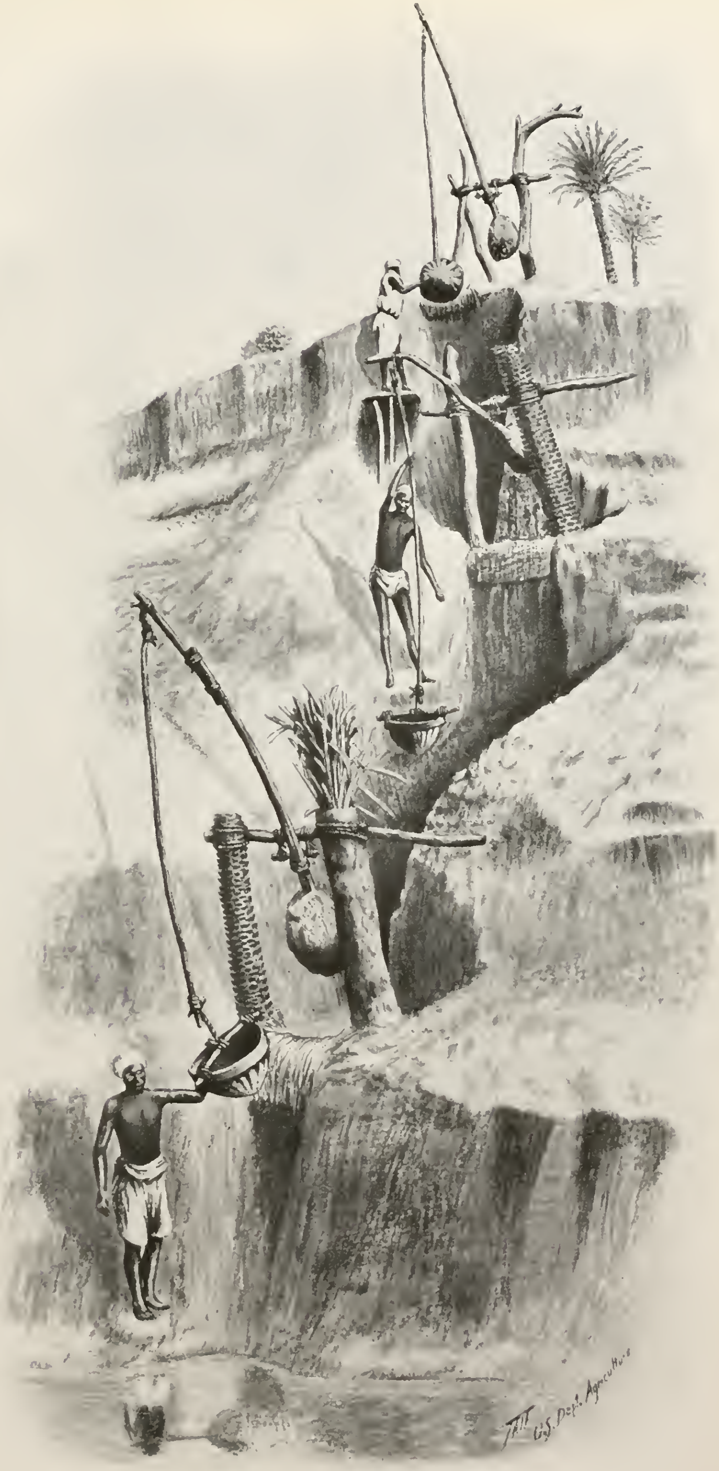


FIG. 2.—HEAD GATE OF MANUFIA CANAL.


U.S. Dept. Agriculture

THE SHADUF.

is approximately 2½ gallons, or one-third of a cubic foot. The counterweight is generally a piece of sun-dried Nile mud held together with straw, cornstalks, or sugar-cane leaves. The woodwork is generally rough and the whole structure shows a lack of neatness. The operator throws his weight on the sweep, the bucket fills, and the counterweight raises it to the channel into which it is to be poured. The ground where the water falls is protected from erosion by a matting of vegetable fiber. A single shaduf can lift water only 5 or 6 feet, but it is the custom to install them in series of three or four, which work together, raising the water from 20 to 30 feet. A number of shadufs so operated need not necessarily be in a line. It is quite common to find the lower shaduf 50 or even 100 feet up or down stream from the others, but it is better to get them as close together as possible, to reduce the loss by seepage.

A shaduf operated by one person can raise about 3 cubic feet of water per minute. A man usually works two hours at a time, and two men relieving each other put in about ten hours a day. They can, therefore, with one machine, raise 1,800 cubic feet of water per day. Assuming that at each irrigation the land is covered to a depth of 1 inch, a device of this kind would irrigate about half an acre a day. The following table shows the efficiency of a number of shadufs on which data were obtained:

Efficiency of the shaduf as a water-raising device.

Height of lift.	Number of shadufs in series.	Cost of running machines per day of ten hours.	Area irrigated in ten hours.	Cost per acre each irrigation.	Discharge per day.	Area of field irrigated.	Cost per acre for each foot of lift.
			Acre.		*Acre-foot.*	*Acres.*	
2.8 feet	1	$0.30	0.21	$1.43	0.06	0.98	$0.51
3.3 feet	1	.32	.17	1.88	.06	1.21	.57
3.3 feet	1	.30	.19	1.58	.07	1.48	.48
3.9 feet	1	.30	.19	1.58	.05	1.40	.41
4.2 feet	1	.29	.15	1.93	.05	.91	.46
5.7 feet	1	.30	.18	1.67	.06	1.15	.29
5.8 feet	1	.30	.12	2.50	.04	1.13	.43
9.1 feet	1	.35	.12	2.92	.05	1.09	.32
10.4 feet	2	.66	.10	6.60	.03	1.01	.63
15.8 feet	2	.65	.10	6.50	.03	.96	.41
19.3 feet	2	.60	.09	6.67	.03	.96	.34
19.4 feet	3	.95	.10	9.50	.03	.81	.49
21.5 feet	3	.86	.08	10.75	.03	1.02	.50
22 feet	3	.90	.08	11.25	.03	.85	.51
29 feet	4	1.23	.08	15.37	.03	.77	.53
29 feet	4	1.39	.08	17.37	.03	.80	.60

THE SAKIYEH.

The sakiyeh is as common as the shaduf. It is estimated that there are 12,000 of them in that part of the delta between the branches of the Nile. There are probably 50,000 altogether in Egypt. The machine is constructed as follows: A horizontal wooden wheel about 10 feet in diameter, furnished with cogs projecting about 8 inches from its circumference, is supported on a vertical shaft, the lower end of which is pointed and rests on a wooden bearing. The upper end of this shaft is generally of small diameter and is thrust through a hole in a horizontal beam 22 or 23 feet long and supported at its ends by columns of sun-dried bricks or masonry. Sometimes wooden posts or even two small pieces of wood crossed and tied together are substituted for these columns. Projecting radially from the horizontal wheel is an arm to which is hitched the animal furnishing the power. The teeth on the horizontal wheel engage similar teeth on a vertical wheel, the shaft of which passes underground to a second vertical wheel over the water to be lifted. The details of this wheel and the earthen jars it carries are shown in the accompanying illustration (Pl. XIII, fig. 1). Where the lift exceeds half the diameter of the wheel the jars are attached to a belt which passes around a small wheel in the water or simply hangs by its own weight. Sometimes the sakiyeh is built on a masonry foundation. The shaft of the horizontal wheel then has a stone bearing and the beam supporting the shaft rests on the masonry walls. While the wooden parts have to be replaced quite often, the masonry work is practically permanent.

An ox or a buffalo is usually employed to work the machine. Each animal is relieved every three hours and generally works two periods per day. Sometimes two animals are driven together. This is common when a double belt, furnished with jars quite close together, is used, or where the lift is very high. In the Fayum the sakiyehs are often turned by the current of the canals. In the delta the vertical wheel carrying the jars is frequently replaced by one having small compartments built in its circumference. The jars ordinarily used on a sakiyeh weigh about 2½ pounds each and hold about half a gallon. A sakiyeh will raise from 120 to 180 cubic feet of water per hour, depending upon the height of the lift. The efficiency of the device is reduced by its lifting the water higher than necessary by about a third of the diameter of the wheel. It has been estimated that one sakiyeh will do the work of four shadufs. This is approximate and is doubtless too high.

A number of improvements have been made in these machines recently and they are now manufactured by British firms and imported into Egypt. Being constructed of iron, the first cost is often prohibitive, repairs are difficult, and it is not easy to install them where the sites have been designed for larger sakiyehs.

The cost of operating a sakiyeh, using one animal at a time, is about $1.50 per acre each irrigation, for lifts not exceeding 12 feet. From 12 to 18 feet the cost will probably reach $2.40 per acre, and from 20 to 30 feet, $3.60 per acre. If the animals used are owned by the irrigator, the cost will be considerably reduced. The sakiyeh itself may cost all the way from $10 to $150, depending upon the location, the cost of the material of which it is constructed, the price of labor, and whether or not masonry is used in the walls and foundation. The following table has been prepared from notes taken in the field:

Efficiency of the sakiyeh as a water-raising device.

Height of lift.	Number of animals working two or two and a half hour periods.	Cost of running machines per day of ten hours.	Area irrigated in ten hours.	Cost per acre each irrigation.	Discharge per day.	Area of field irrigated.	Cost per acre for each foot of lift.
			Acre.		*Acre-foot.*	*Acres.*	
3 feet	2	$0.60	0.74	$0.80	0.24	10.3	$0.27
5 feet	2	.60	.66	.90	.23	8.6	.18
5.50 feet	2	.63	.66	.95	.24	8	.17
6 feet	2	.58	.78	.74	.21	9.4	.12
7.75 feet	2	.51	.65	.80	.21	7.3	.10
8.75 feet	2	.69	.65	1.06	.20	7.6	.12
10 feet	2	.60	.64	.94	.23	7	.09
12 50 feet	2	.57	.57	1.00	.26	6.1	.08
16 feet	2	.49	.66	.74	.20	7.2	.05
19 feet	3	.82	.47	1.74	.17	5.3	.09
5 feet	4	1.05	.49	2.14	.16	4.8	.09

THE ARCHIMEDEAN SCREW.

In the delta a number of unusual methods are employed for raising water from 1 to 4 or 5 feet. One of the most striking of these, and one the least to be expected in Egypt, is the Archimedean screw. Around an iron shaft some 14 or 15 feet long is built a screw, made up of thin pieces of wood so fitted together as to be practically water-tight. A water-tight wooden cylinder is constructed around the screw. The diameter of the cylinder is ordinarily about 14 inches, and its length does not often exceed 8 or 9 feet. The pitch of the screw is about 1 revolution to 1½ diameters. The screw is so attached that it will not revolve on the shaft. The shaft projects from both ends of the cylinder and is supported near its extremities by posts. The screw inclines 30 degrees or less to the horizon, with its lower end in the water. To the upper end of the shaft a crank is attached. This lifting device is shown in the accompanying illustration. (Pl. XIV.) One or two men usually operate a screw, but in rare cases, when the screw is especially large or the lift considerable, a small engine is employed. High lifts are practically impossible on account of the difficulty of supporting a screw of great length. This device is more efficient than the lifting machines contrived by the natives. One man can irrigate from 1 to 2 acres a day with this machine, provided the lift be not over 2 feet. The efficiency of the Archimedean screw is shown in the following table:

Efficiency of the Archimedean screw as a water-raising device.

Height of lift.	Number of men working periods of two hours.	Cost of operation per day of ten hours	Area irrigated in ten hours.	Cost per acre each irrigation.	Discharge per day.	Area of field irrigated.	Cost per acre for each foot of lift.
			Acres.		*Acre-foot.*	*Acres.*	
3.3 feet	2	$0.31	1.22	$0.25	0.47	14.2	$0.08
4.5 feet	2	.27	1.12	.24	.49	10.8	.05
4.6 feet	2	.27	1.36	.20	.52	10	.04
5.1 feet	2	.29	1.02	28	.45	6.4	.06
5.9 feet	2	.30	1.14	.26	.41	11.7	.04

THE NATALI.

In the delta a great deal of water is raised by means of another curious device, known as a natali. Two men operate a bucket to which is attached four cords. These cords are held by the men and the bucket is alternately filled and emptied with remarkable dexterity. Pl. XV shows this device in use. But little preliminary construction is needed before the work of raising water can be commenced. A channel is generally dug from the water into the bank of the canal and platforms are made for the men to stand on. Where the water is poured into the ditch leading to the fields the bank is protected, as in the case of shadufs, by a matting of vegetable fiber. Two men can raise about 100 cubic feet of water per hour to a height of 3 or 4 feet. The accompanying table gives some information relative to the efficiency of this contrivance:

Efficiency of the natali as a water-raising device.

Height of lift.	Number of men working periods of two hours.	Cost of operation per day of ten hours.	Area irrigated in ten hours.	Cost per acre each irrigation.	Discharge per day.	Area of field irrigated.	Cost per acre for each foot of lift.
			Acre.		*Acre-foot.*	*Acres.*	
0.7 foot	2	$0.28	0.94	$0.30	0.27	6	$0.43
0.8 foot	2	.30	.98	.31	.26	6	.39
1.0 foot	2	.28	.88	.32	.26	7.2	.32
1.5 feet	2	.30	.66	.45	.21	6.6	.30
1.6 feet	2	.30	.51	.60	.21	5.1	.38
1.9 feet	3	.46	.78	.60	.24	5.4	.32
2.1 feet	2	.31	.65	.48	.20	6.3	.23
2.3 feet	4	.58	.64	.90	.22	5.1	.40
2.7 feet	4	.65	.71	.91	.20	5	.34
2.8 feet	4	.54	.70	.77	.20	4.6	.27

PUMPING.

Small pumping plants are becoming common and some expensive and well-equipped pumping stations have been erected in various parts of Egypt. The design most commonly met with is an 8-inch centrifugal pump propelled by an 8-horsepower steam engine. Coal is usually burned in these engines, although cornstalks and straw are substituted for it in Upper Egypt. Coal costs $7 per ton at Alexandria, the price increasing with the distance from that port.

As early as 1882 there were 2,645 pumps and engines lifting water from the Nile and from canals. The engines had a total horsepower of 29,453. Of the plants 2,226 were movable and 419 were stationary. The stationary engines had a total horsepower of 9,382, while the movable engines had a horsepower of 20,071. Nearly all of these pumping plants were located in the delta, although there were a number between Cairo and Assiut. Above that there were no movable plants and only 17 stationary engines and pumps. The number has not increased appreciably since that time, but modern pumps have,

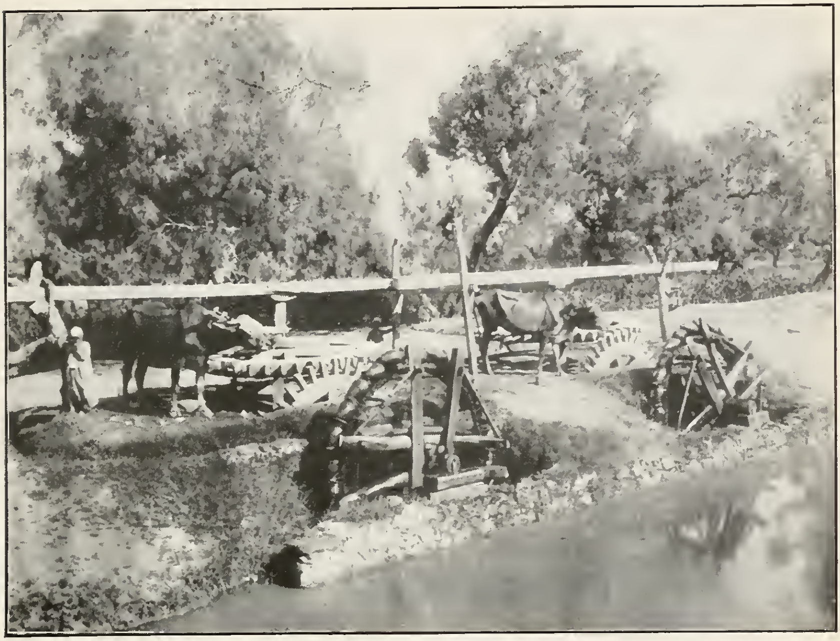


FIG. 1.—SAKIYEHS.

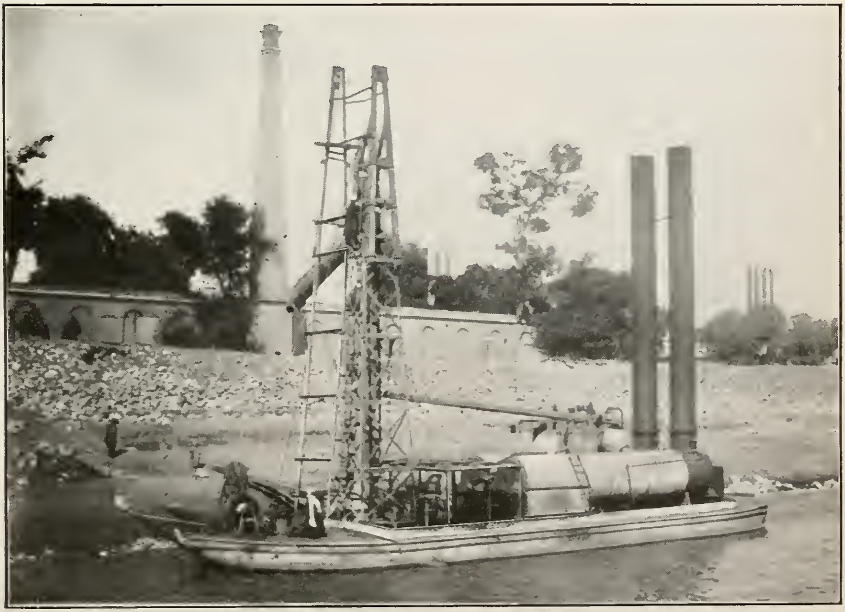
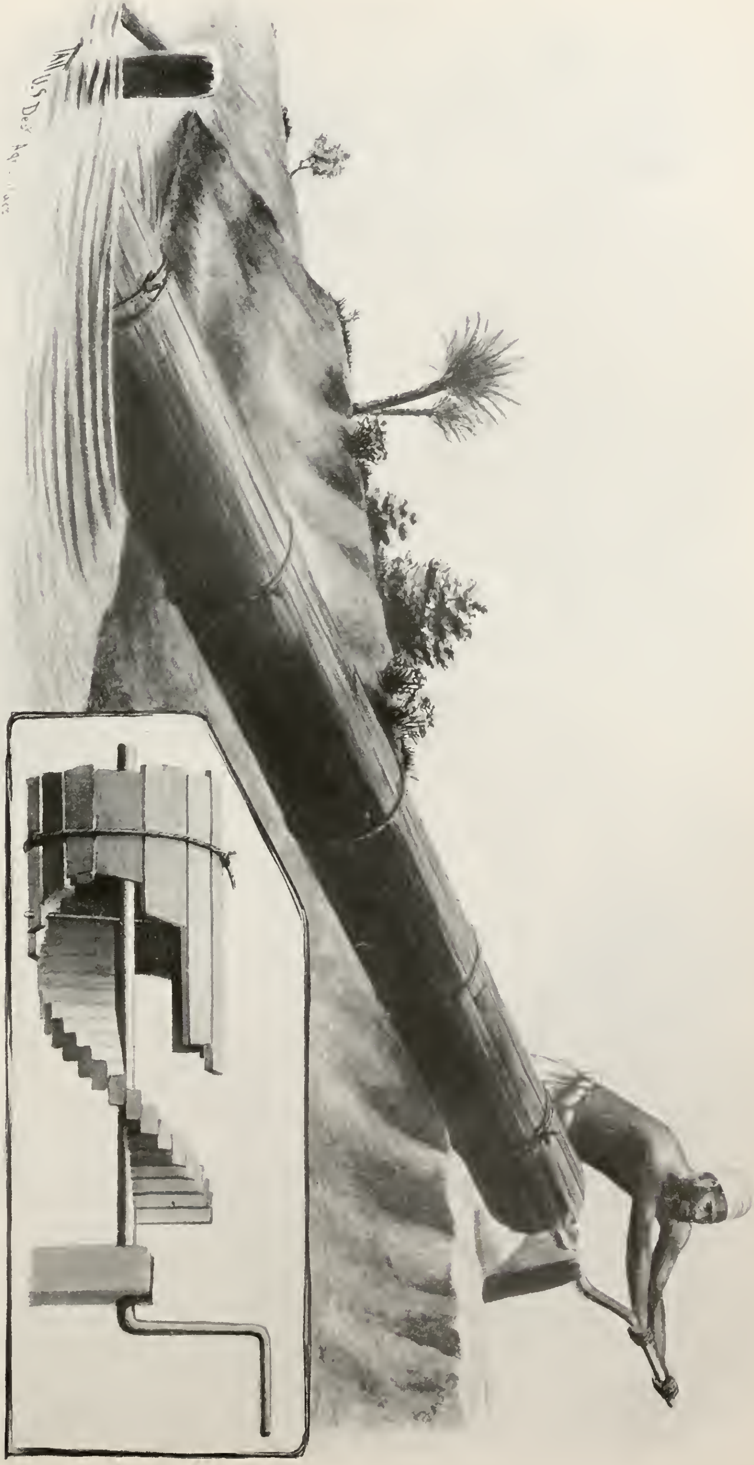
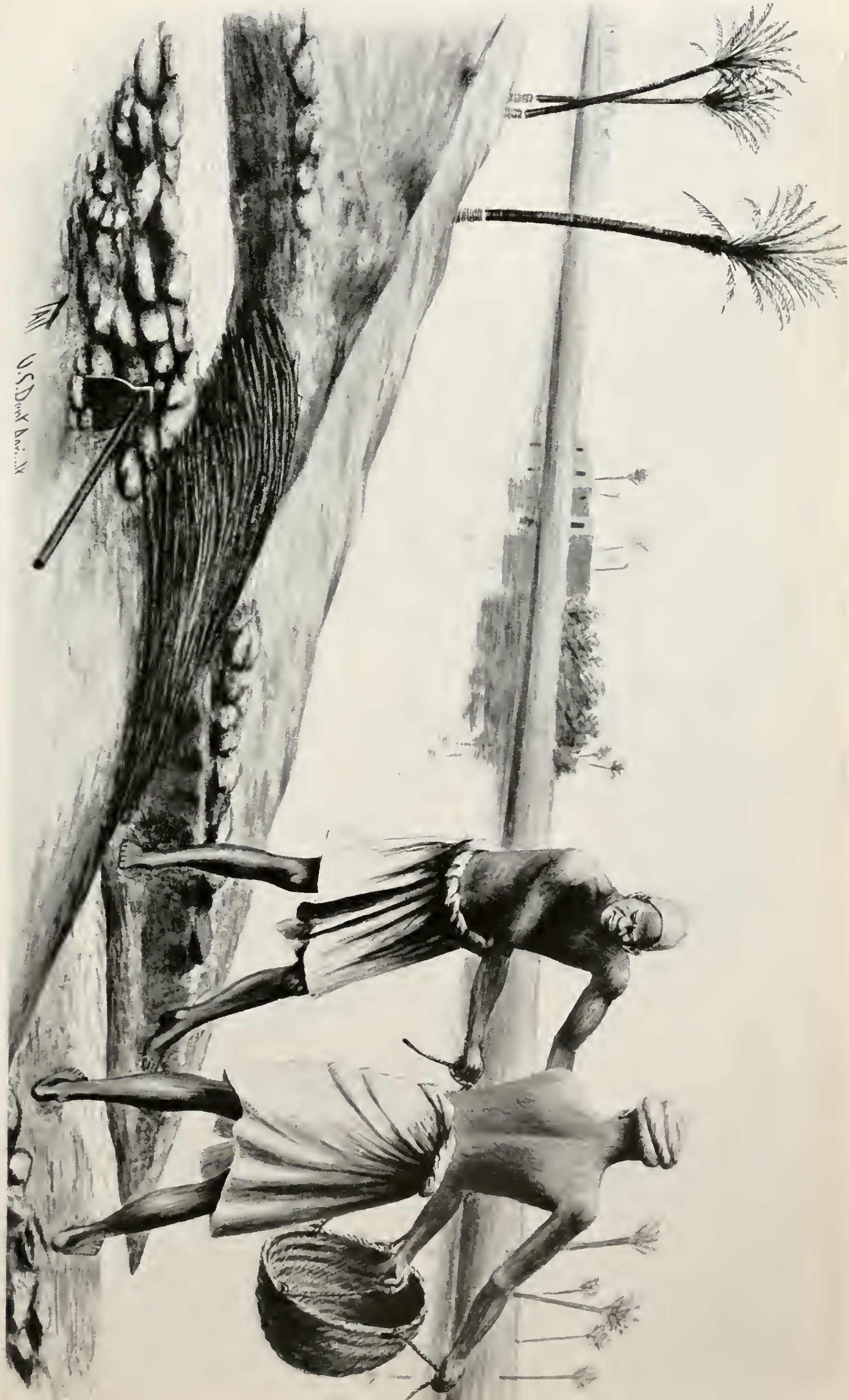


FIG. 2.—A STEAM PUMP ON A SCOW.



ARCHIMEDEAN SCREW, SHOWING INTERIOR CONSTRUCTION AT RIGHT.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THE NATALI.

in many cases, been substituted for those originally employed. Pumping plants are frequently seen on scows on the river. (Pl. XIII, fig. 2.) These go from place to place and furnish water under contract. Where the lift is not over 8 or 10 feet and where the owner of the field is a part owner in the plant, steam pumps furnish water at about $1.90 per acre for each irrigation. If the farmer is not interested in the plant the cost per acre may run as high as $3.75 or $4 for each irrigation. Cotton has to be watered four or five times during the growing season. Wheat, maize, and all fodder crops are generally twice irrigated. Figures quoted by engineers as to the cost of pumping water vary greatly. The outlay for this service depends largely upon the local practice of the irrigator. Mr. Thorwald L. Smith, agriculturist of the Société du Béhèra, which controls a considerable area in the delta, has furnished the following information regarding the character of the pumps employed by the society, together with their discharge, the quantity and cost of coal consumed, etc. The pumps employed are either of English or French manufacture, and are not superior in any way to those made in the United States. A detailed description of them is therefore unnecessary.

Efficiency of pumping plants owned by the Société du Béhèra, Alexandria.[a]

Description of centrifugal pump and engine.	Discharge per second.	Expense of operation per day of ten hours.				Total cost per day.	
		Coal.[b]		Lubricants and sundries.	Engineer and fireman.	Ten hours.	Twelve hours.
		Pounds.	Cost.				
	Cubic feet.						
20-inch direct-acting compound condensing Gwynne pump	17.66	1,212	$5.45	$0.18	$1.23	$6.83	$8.13
20-inch Ruston and Proctor, driven by belt from semiportable compound condensing engine by same makers	17.66	1,212	5.45	.18	1.23	6.83	8.13
18-inch Dumont pump, driven by belt from a Ruston-Proctor compound condensing portable	17.66	1,212	5.45	.18	1.23	6.83	8.13
16-inch Ruston-Proctor pump, driven by belt from compound condensing portable by same makers	10.60	772	3.47	.18	1.23	4.86	5.83
12-inch Gwynne pump, driven by belt from single cylinder non-condensing portable	6.70	662	2.98	.18	1.23	4.86	5.83

[a] Tests running from 1895–1901; lift, 6.5 feet.

[b] Coal at $8.94 per ton.

DUTY OF WATER.

Some tests have been made in both Upper and Lower Egypt to determine the duty of water. The lack of careful measurements of the water supplied for irrigation discredits many reports which would otherwise be valuable. The rated capacity of the pumps is too often used in computing the volume of water furnished. When gaugings are made to check the pumps, it is generally found that the discharge has been overestimated. The water is usually measured on the border of the field, so that but little loss occurs between the pump and the irrigated land. In lower Egypt it has been found that a depth of water of 2.55 feet is sufficient for the irrigation of cotton. A depth of 4.3 feet is required for rice. The winter crops, which have already been enumerated, demand from 1.6 to 2 feet. Although the growing season of sugar cane, the most valuable crop in upper Egypt, covers a period of nine months, a depth of water of 2.5 feet suffices for its needs.

The following discussion of the duty of water under some of the pumping plants of the Société du Béhèra, in Lower Egypt, has been furnished by Mr. Thorwald L. Smith:

* * * The loss through evaporation and absorption varies greatly according to the following conditions:

(1) Quality of soil: (a) Sandy; (b) medium; (c) heavy.

(2) Time of year: (a) Hot; (b) cold.

(3) Number of days elapsed since last watering.

(4) Distance of field from pump: (a) Water carried in old permanent channel; (b) carried in temporary channel for that particular crop.

As to the first, we find that in (a) sandy soil (pure alluvial deposits) the quantity of water required for each watering is about double that wanted for heavy (c). On the other hand, such soil cracks less, and, consequently, there is not so much loss, should the time between two waterings be prolonged, as there is in heavy soil where, after a long drought in summer, the cracks (unless the land be frequently hoed) will continue to absorb all the water for some minutes and will conduct it to the subsoil, which is salt, where it can be of little use to the surface-feeding crops.

Second. Time of year makes a difference in two ways: First, because in summer a lot of water is lost by evaporation so soon as it is spread in a thin layer over the baked land, and second, because in the cooler months the canals are all generally running full and consequently all low lands can be irrigated by gravitation and are more or less water-logged, especially where drainage is bad. In fact, for winter crops the only time when pumps are used for such lands is when the upper reaches of the canals have been closed for clearance and the water in the lower reaches falls below the ground level.

Third. The number of days between each watering for cotton should be an average of fifteen, but through want of water this is frequently prolonged to thirty or even more. Naturally from causes mentioned above, i. e., cracking, and from the fact that evaporation directly and through the plants has been going on continually, the land takes more water to show any sign on the surface. For the rice crop these last conditions can not obtain, for water must be changed in rice fields while the crop is young at least every four days, and when stronger at a maximum of eight days on good soil. (Where the land is very salt the crop would suffer very much, if not die, in an eight-day interval.) On the other hand, as the rice land is continually wet the absorption at the time of watering is much less, and of course there are no cracks. However, as the water is on the surface there is great evaporation from sun and wind, especially so long as the plant is small and does not shade its own roots.

In calculating (theoretically) the amount of water necessary for each watering, about 3.94 inches in depth would appear to be sufficient. Indeed, in the case of cotton which is sown on ridges, one might think that the area of the furrows only, into which the water runs, i. e., about half the total area, would be the figure on which to base the quantity necessary. But the ridges, being made up entirely of loose soil, soak up water at once, especially the first watering or after a hoeing, and carry almost as much as a furrow. I may say at once that the 3.94 inches over the whole area for cotton, even when the ground is not much cracked, is quite insufficient, and in a long furrow that quantity would not reach the end. Of course, to equalize the supply to each plant the field is divided longitudinally into narrow belts and these belts crossways into short beds. This division is made after the field has been prepared and ridged up, the original ridges stretching from one end of the field to the other. Between each belt is a small water channel, which is what I refer to in 4 (b). In these channels a good deal of water must be wasted. As to the permanent waterways we calculate a mean loss of 10 per cent for absorption and evaporation. * * *

THE CAIRO BARRAGE.

In 1798 and 1799, during the French occupation, Napoleon called attention to the advisability of constructing dams across the Rosetta and Damietta branches of the Nile. Perennial irrigation had probably not occurred to him, but he saw the advantage of being able to turn the whole discharge of the river down one branch or the other so that the lands along either might receive the benefit of the entire flow. The dam would probably not have been built had this been its only function, but his suggestion may have led Mohammed Ali to introduce perennial irrigation in Lower Egypt.

In 1833 Mohammed Ali favored building a stone dam across the Rosetta Branch so that it might be entirely closed. This would raise the level of the water considerably at the site of the dam and afford a better supply to the canals taking water from the Damietta Branch, along which was the larger irrigated area. Before work was begun he was persuaded to change his plans. It was suggested to him that in place of building a dam across the Rosetta Branch one be erected on each branch 6 miles below their point of divergence. The khedive approved this plan and ordered that the stone be taken from the Pyramids. All protests against this latter scheme were without avail until Linant Pasha, a government engineer, showed that, as the Pyramids were built from the bottom to the top, they would have to be dismantled from top to bottom, and that the stone thus procured would be more expensive than if taken from new quarries opened near Cairo. Everything seemed now to promise speedy completion of the dam. Workshops were erected and some material for construction had been delivered on the ground, when Mohammed Ali again changed his mind and stopped the work. Nothing more was heard of the barrage project until 1842, when Mougel Bey, a French engineer, was called to Egypt and his plans, as altered by the khedive so as to include the fortifications, led to the construction of the barrage as it stands to-day. The dam was finally completed in 1861 at a cost of $9,000,000, not counting the services of the corvée. The additional cost of fortifications, canal head gates, and incidentals made the total outlay about $19,000,000.

After this vast expenditure the dam was of no value except as a highway across the Nile. Only the Rosetta Branch of the barrage was supplied with gates. The additional head produced by closing these caused enough pressure to crack the masonry of the dam. At the same time water ran under the structure and a number of springs appeared below. During the reign of Ismail Pasha nothing was done toward repairing the barrage. Suggestions that it might be put in condition to hold back water for the irrigation of lower Egypt were never considered seriously.

The barrage is shown in the accompanying illustrations (Pls. XVI and XVII). The Rosetta dam has 61 archways, while the Damietta Branch has 71. The height of the archways is 41.82 feet from the floor of the structure to the crown of the arch, or 32.8 feet to the spring line of the arches. The archways are 16.4 feet wide, and the piers supporting them are 6.56 feet thick. The original foundation of the dam was simply a layer of concrete 111 feet wide and nearly 9 feet thick, covered by a stone and brick floor 1.64 feet thick. As work on each section was undertaken, sheet piling was driven to keep the water quiet while the concrete was being laid. The piers were constructed on this floor. Locks were built at both ends of each dam and at the head gates of the three canals. The flow of water through the sluiceways was to have been regulated by gates of a new design, but they never proved satisfactory, although a few still remained in the dam until 1890. The gates now used close tightly, but a grating, through which the water flows at all times, is beneath the sills on which the gates rest.

Since the English have been in control of Egypt repairs to the barrage have been going on almost constantly. A new floor was laid, widening the foundation 30 feet on the downstream and 78 feet on the upstream side. It was thought better to widen rather than deepen the foundation, because the material did not improve with depth. After this work was completed new gates were put in the dam throughout. These were made of wrought iron and provided with rollers, and they slide in cast-iron grooves made fast to the piers. The gates are lifted by a traveling winch. One rail for supporting the car carrying the lifting device was put on the upstream parapet of the dam. Brick towers were built on the piers to support the second rail. These towers, with the gates now employed, are shown in Pl. XVII.

Until 1896 the springs on the downstream side of the dam continued to flow. Some water came through the gratings, but a large volume flowed under the piers. In 1896 repairs were begun which will doubtless make the barrage an enduring structure. Through holes 5 inches in diameter, drilled from top to bottom of the piers and lined with iron pipes, clay or cement mortar was rammed. It was found in this work that large cavities existed under the foundation, and as much as 40 barrels of cement were used for a single pier. The total cost of

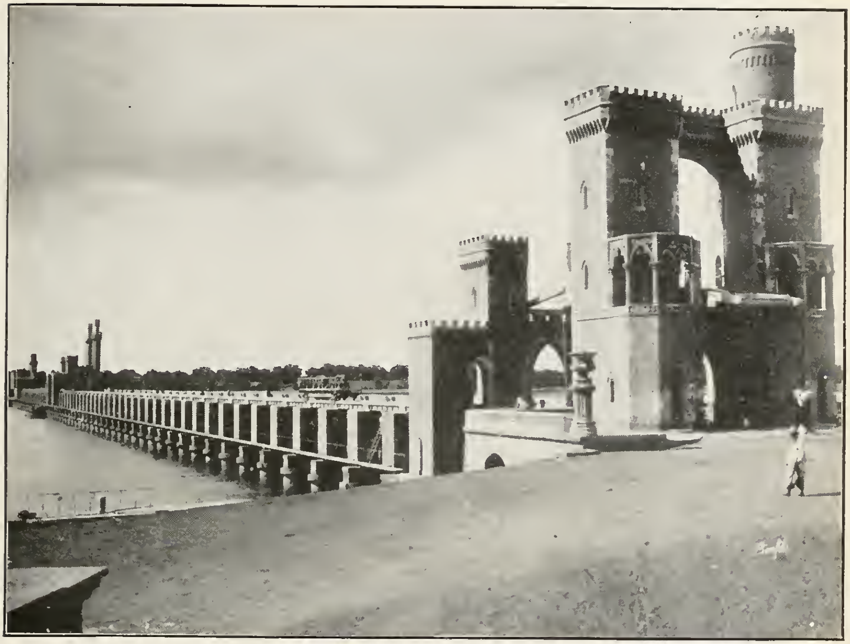


FIG. 1.—THE DAMIETTA BARRAGE FROM EASTERN BANK OF THE NILE.

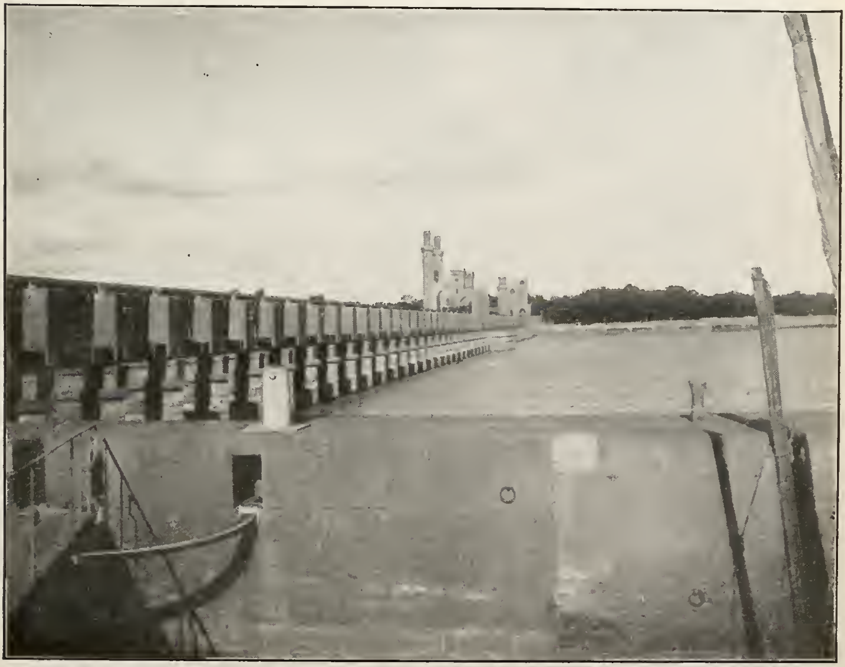
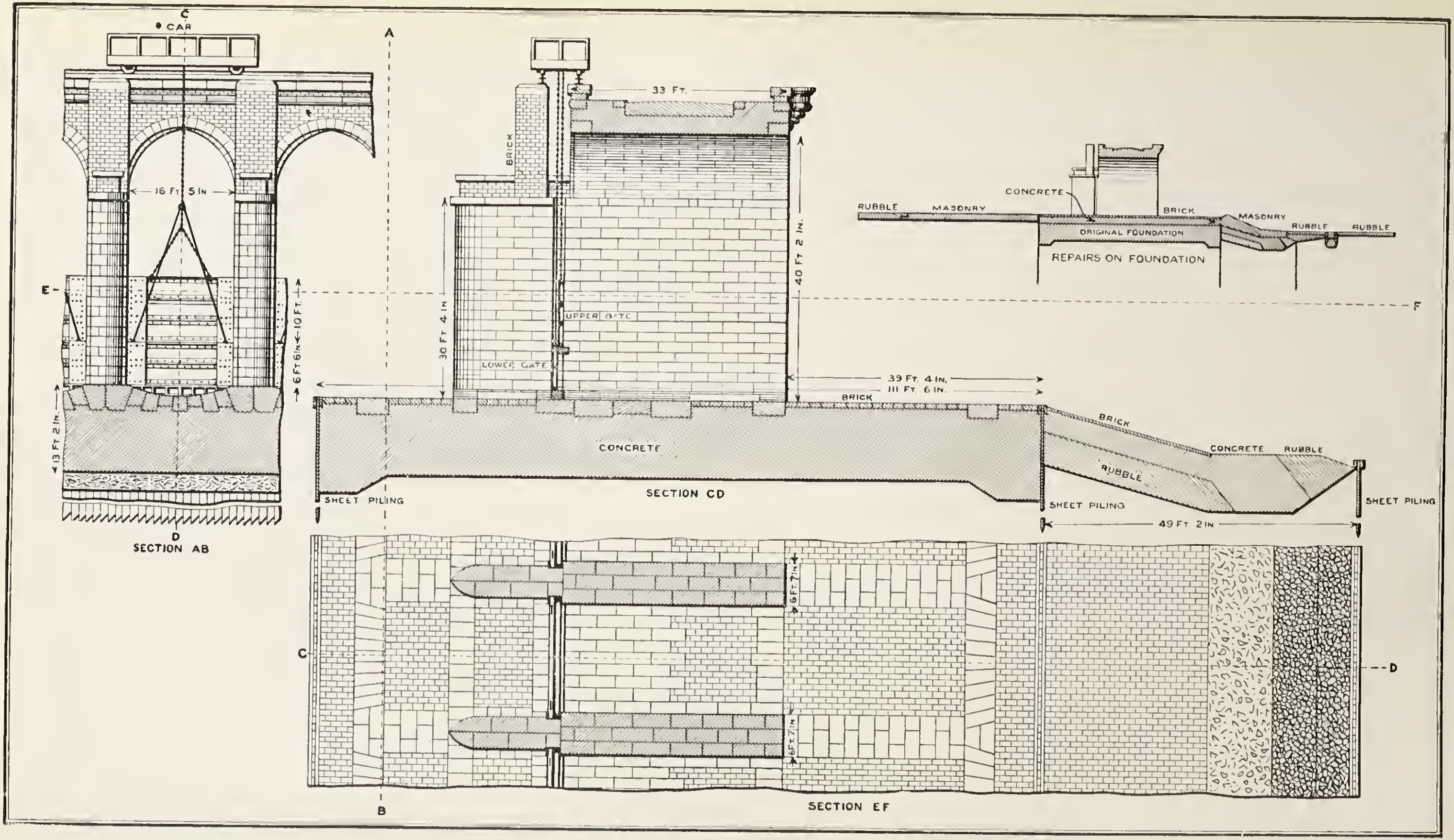


FIG. 2.—ROSETTA BARRAGE FROM WESTERN BANK OF THE NILE.


C
CAR
A
16 FT 5 IN
E
10 FT.
6 FT 6 IN
13 FT 2 IN.
D
SECTION AB
33 FT.
BRICK
30 FT 4 IN
UPPER GATE
LOWER GATE
40 FT 2 IN.
39 FT. 4 IN.
111 FT. 6 IN.
BRICK
CONCRETE
SHEET PILING
SECTION CD
BRICK
RUBBLE
CONCRETE
RUBBLE
SHEET PILING
SHEET PILING
49 FT 2 IN.
RUBBLE
MASONRY
CONCRETE
BRICK
MASONRY
RUBBLE
RUBBLE
ORIGINAL FOUNDATION
REPAIRS ON FOUNDATION
F
6 FT. 7 IN
6 FT. 7 IN
C
D
B
SECTION EF

DETAILS OF THE CAIRO BARRAGE.

these repairs amounted to $300,000. Another safeguard has been added to the barrage. Across each branch of the Nile below the barrage low dams have been built, raising the surface of the water there and correspondingly reducing the pressure to which the larger works are subjected.

The Egyptian Government had many times prior to 1882 discussed the matter of repairing the barrage. At one time a scheme was on foot whereby it was thought that an expenditure of $6,200,000 would make the structure serviceable. Luckily, the Arabic custom of not making repairs prevailed in this instance. Another scheme which received the attention of the government was to pump water into the canals instead of relying on the barrage at all. This would have necessitated an expenditure of nearly $3,500,000 for the establishment of the pumping plant, and an annual outlay of about $1,250,000 to keep it in operation. The government actually made a contract with a company to pump water into one of the canals during low water, and bound itself to pay at least $128,000 a year for this service. So successful, however, were the engineers in repairing the dam that by 1892 the canals heading there were fully supplied. The barrage furnishes water at a much less cost than a pumping plant, and, as the flow is regulated during the season of high water as well as at other times, a great reduction is made in the volume of silt which has to be removed from the canals each year. However, until after the occupation of the English, labor had but little value, and this item was probably not taken into consideration.

As early as 1884 the barrage performed some beneficial service for the irrigators of the delta. The alterations which first put the dam in working order cost about $2,250,000. One hundred and fifty thousand dollars are required each year for maintenance and operation. While the repairs were being carried on, the Tewfiki Canal, taken out at the eastern end of the Damietta branch of the barrage, was completed. Many auxiliary canals and ditches were dug and considerable reform was brought about in the drainage system throughout the delta.

RESERVOIRS.

The construction of reservoirs is a new departure on the part of the Egyptian Government. Storing water at Assuan during the winter for the benefit of the irrigator during the months of scarcity will necessitate changes in the irrigation systems now existing if the supply thus made available is to be distributed to the best advantage. The water supply afforded by the Nile is such that storage works can be extended almost indefinitely, or until all of the arable land of Egypt is served by perennial irrigation.

The total area of Egypt proper, embracing the great Lybian Desert, which contains five oases and a large part of the Sinai Peninsula, is about 390,000 square miles. Of this less than 3 per cent, or about 6,000,000 acres, can ever be cultivated. The accompanying map (Pl. XVIII) enables a comparison to be made of the Nile Valley with that of the Platte River. It will be noticed that the mouths of the Platte and the Damietta branch of the Nile are coincident. The two rivers cross the north boundary of Colorado near the same point, and Denver and Assuan lie only a few miles apart. Egypt proper, therefore, has about the same length as the Platte Valley from Denver to the Missouri River. The width of the Platte Valley in Nebraska is about the same as that of the Nile from Assuan to Cairo. Only 5,145,000 acres are now cultivated in the valley of the Nile. A similar area of agricultural land in Nebraska would have produced in 1900 crops having a total value of about $26,000,000. The farming lands of Egypt pay more than this in taxes each year. Nebraska received in 1900 a little over $6,000,000 from all its sources of revenue. Egypt received about $60,000,000. Nebraska has no bonded indebtedness and but a small floating debt. Egypt has a complication of financial troubles, owing in the aggregate $516,000,000, or $100 for each acre of agricultural land.

But little arable land in Upper Egypt remains unreclaimed, and the area enjoying perennial irrigation can not be extended until reservoirs are provided to store the water which is needed in May and June. With the growth of the reservoir system basin irrigation will disappear. There are now 120 of these basins in Upper Egypt, varying in size from 500 to 35,000 acres. Each year many of these basins fail to receive the volume of water needed and the yield of the crops is correspondingly reduced. Taxes on such land have to be remitted, entailing a loss to the treasury of $220,000 annually. Although the basin system has been greatly improved during the past twenty years, yet so evident are the advantages of perennial irrigation that the demand for reservoirs has been growing. In Lower Egypt 1,300,000 acres can be reclaimed when water for irrigation is made available. According to a rough determination of the duty of water, made by engineers, it will require 33,000 cubic feet per second, or 75,400 acre-feet per day, to irrigate this land.

The mean discharge of the Nile for January is about 140,000 acre-feet per day. For February it is about 104,000, and for March it is 73,000 acre-feet per day, in this month falling below the volume which will be needed when all the irrigable land in Egypt is brought under cultivation. In April and June the mean discharge per day is about 51,000 acre-feet. In May it falls as low as 44,500 acre-feet per day. The mean discharge in acre-feet per day for July is 182,000. While some shortage may occur very early in this month, yet it is not one of the critical months. During the remainder of the year the river always furnishes more water than is needed.

Mean discharge of the Nile, 1873–1892.

Month.	Acre-feet.	Month.	Acre-feet.
January	4,192,650	August	17,684,568
February	3,115,728	September	20,620,106
March	2,210,858	October	19,650,906
April	1,538,460	November	9,329,760
May	1,335,114	December	5,899,014
June	1,538,460		
July	5,481,600	Total	92,601,224

The reservoir system would, during average years, have to supply 126,000 acre-feet in March, 799,000 acre-feet in April, 1,002,000 acre-feet in May, 799,000 acre-feet in June, and probably 120,000 acre-feet during the first few days of July. The reservoirs would have to store a total volume of 2,852,000 acre-feet in order to furnish water for the irrigation of this land. Even in low-water years the Nile supplies plenty of water to fill a reservoir system of much larger capacity. If the reservoir system could be made large enough to maintain a uniform flow in the river throughout the year, it would at all times discharge about 257,230 acre-feet per day, or about 130,000 cubic feet per second. The Nile furnishes an average volume of 92,600,000 acre-feet annually. Disregarding losses in storage and transit, it is estimated that 27,521,000 acre-feet of water would irrigate all of the agricultural land. Under this assumption the land would be covered to a depth of 4.27 feet. This would leave 65,200,000 acre-feet of water unused when Egypt was fully supplied. It will be seen that the building of the Assuan reservoir, with an estimated capacity of 863,400 acre-feet, is only the first step in the construction of storage works. The Wady Ryan site alone could probably store about 3,000,000 acre-feet, enough water to supply Egypt, but it could be used only in Lower Egypt; but the natural flow of the Nile furnishes more water than is needed for Upper Egypt. If this site were improved, the Assuan reservoir would not be needed; hence, it will very likely be the policy of the government to build a number of storage works similar to the Assuan reservoir farther up the river. That the expense of maintaining these and the difficulty of controlling the discharge of water from them will be much greater than for one large reservoir, can not be doubted.

If reservoirs are constructed farther up the Nile, they must be farther from Egyptian territory, and consequently more difficult to control. Much discussion has occurred as to the feasibility of utilizing lakes Victoria and Albert in central Africa as reservoirs. But little has been done toward making surveys in that locality and no figures are available as to the cost of converting the lakes into storage works.

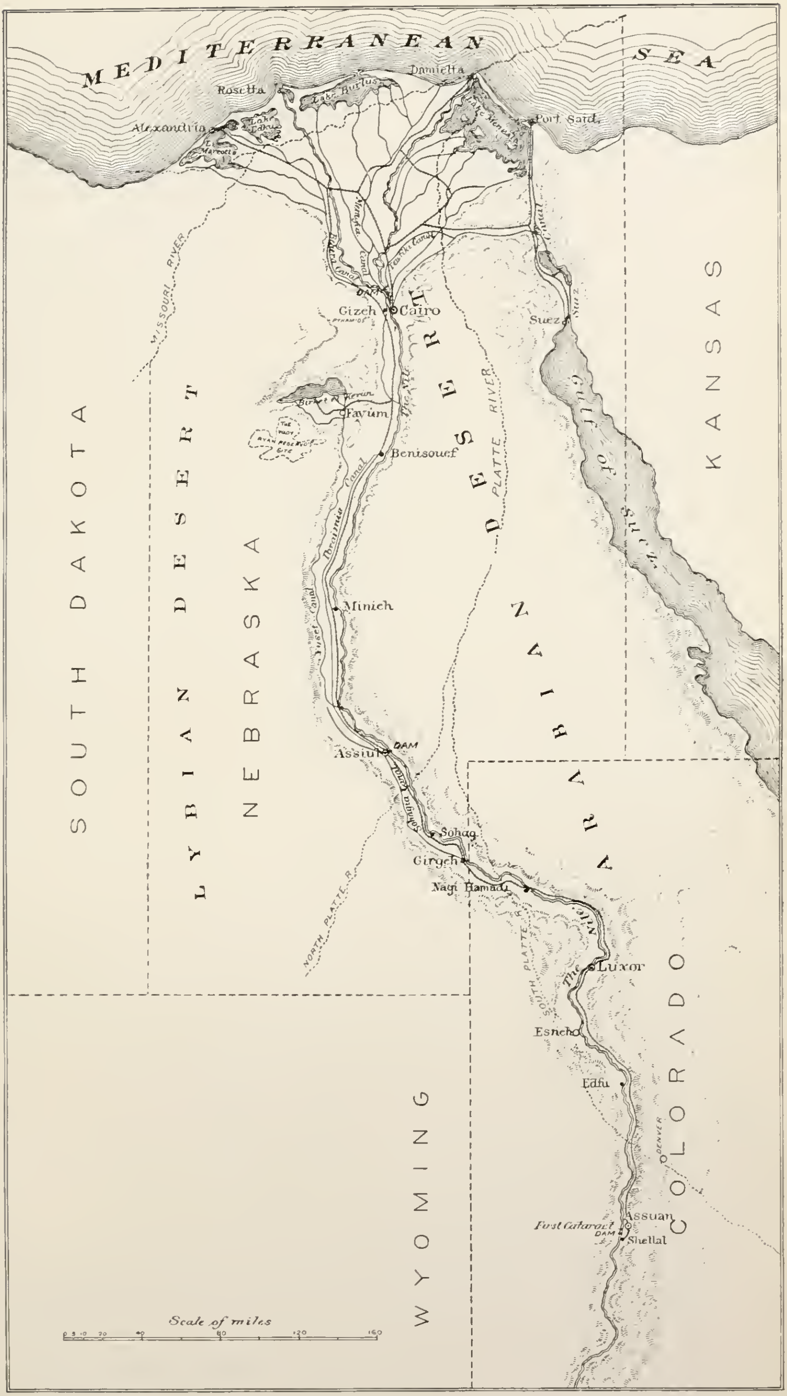
THE ASSUAN RESERVOIR.

The engineers of the Egyptian Government have realized for a long time that it would be necessary to store some of the Nile water before Upper Egypt could receive the benefits of perennial irrigation or a large area of Lower Egypt be reclaimed. For ten years before work was undertaken toward building the reservoir preliminary surveys were made and many reservoir sites were discussed. Investigators resorted to ancient history and brought forth all the known facts regarding Lake Moeris, which occupied part of the basin now known as the Fayum province. One American engineer, who had studied this subject and made some surveys, held that the Wady Ryan was formerly Lake Moeris. Whether or not this be true does not matter at this time. To-day it is the only practicable reservoir site between the Mediterranean and Assuan. (See Pl. XIX.)

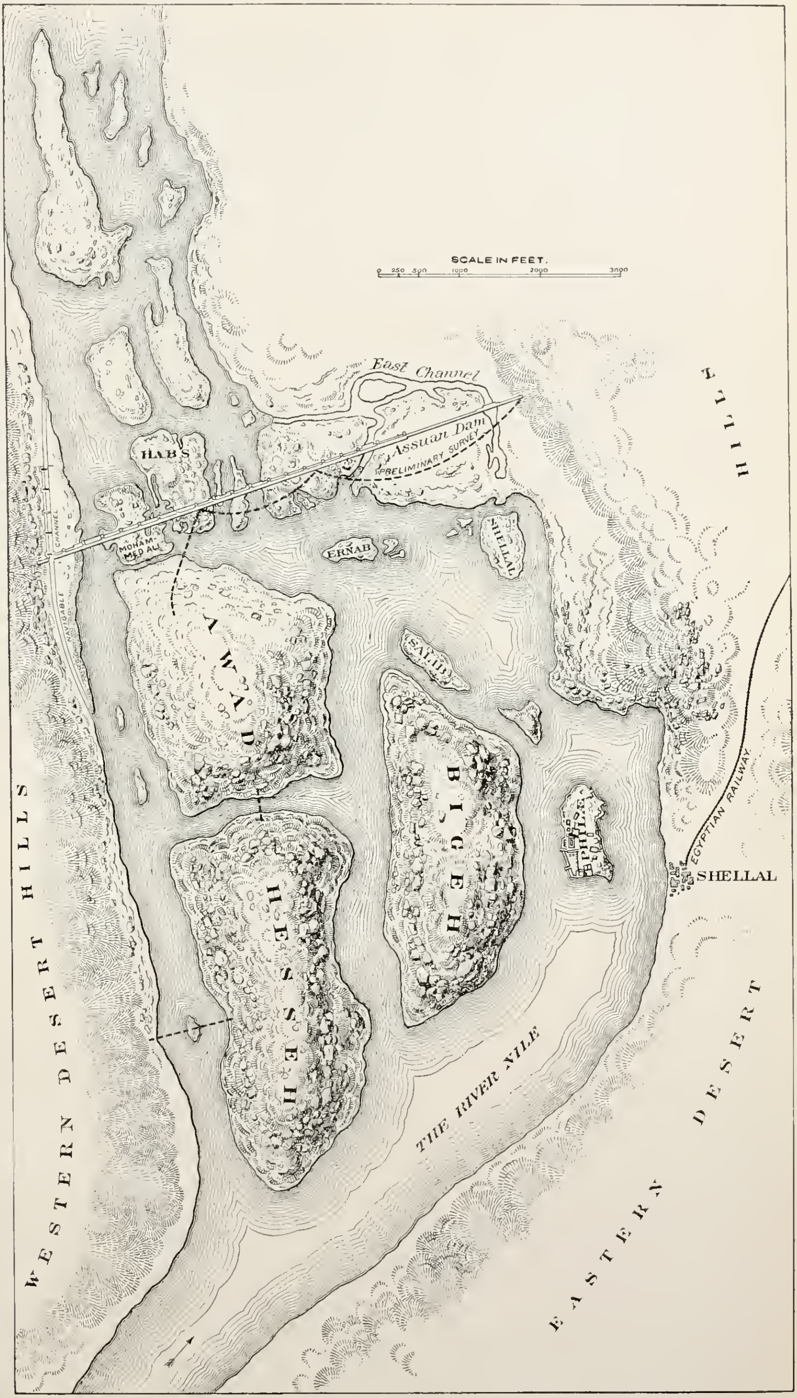
Early in 1894, after considerable discussion as to how reservoir construction should be carried on and what sites should be utilized, a technical commission was appointed. This commission consisted of Sir Benjamin Baker, an Englishman; Auguste Boulé, a Frenchman, and Giacomo Torricelli, an Italian. They left Cairo February 26, and returned March 23, having examined all the sites in less than a month. The Wady Ryan and a number of Nile valley reservoirs were discussed, the majority of the commission finally agreeing upon the Assuan site.

The Nile, from the town of Assuan to the dam site, is broken into many irregular channels. The bed and banks of the river are largely composed of granite. The first cataract of the Nile begins where the water first encounters the granite. Engineers agreed that the dam should be built in this locality, but as to its exact line there was a great deal of discussion. Mr. Willcocks recommended that it be of irregular alignment, running from one island to another, where his studies indicated that the granite was solid, thus affording a good foundation; but the dam as finally built is straight, and crosses the river where rapids first appear. It was originally planned to make the dam 100 feet high, but when it was found that a dam of this height would cause the submersion of the temples on the island of Philae it was determined, in view of the protests of those interested in the preservation of these ruins, to reduce the height 30 feet, although it is possible that it may still be raised to 100 feet. This would give the reservoir a storage capacity two or three times greater than it now has, while the ratio between the cost of the work and the volume of water impounded would be greatly reduced. (Pls. XX and XXI.)

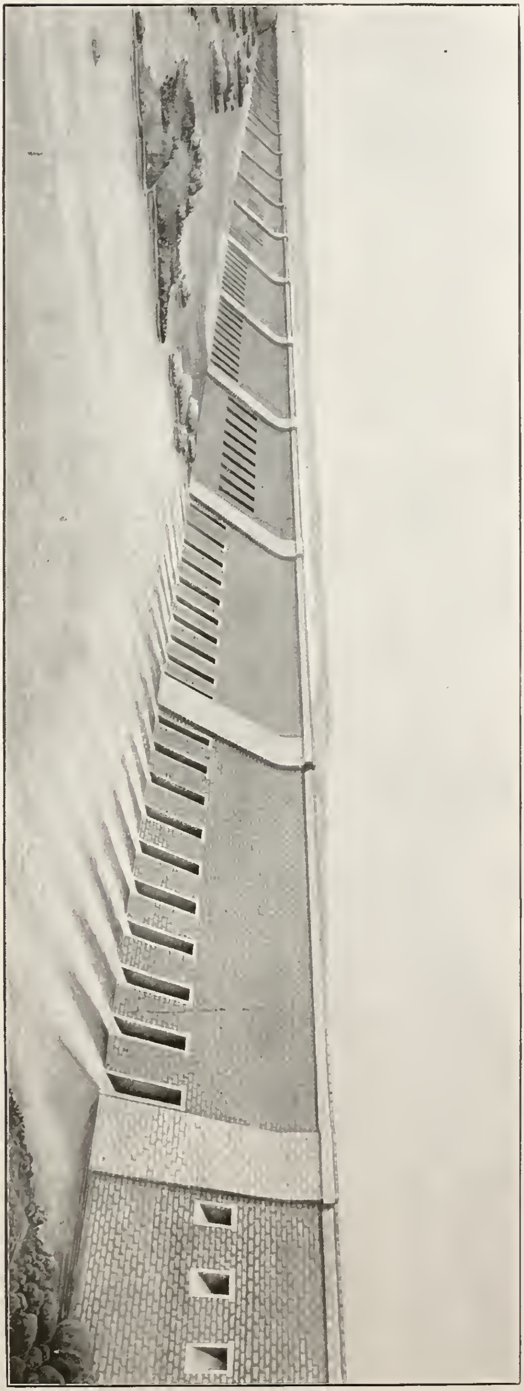
The dam is 70 feet high, 6,400 feet long, 23 feet wide on top, and 82 feet wide on the bottom at the deepest part. It contains approximately 1,000,000 cubic yards of masonry. The depth of water at the


MEDITERRANEAN SEA
Rosetta
Lake Burlus
Damietta
Lake Edku
Alexandria
L. Mareotis
Lake Menzaleh
Port Said
Menufia Canal
Behera Canal
Tewfiki Canal
DAM
Gizeh
PYRAMIDS
Cairo
MISSOURI RIVER
Canal
Suez
Gulf of Suez
Birket el Kerun
Fayum
THE WADY RYAN RESERVOIR SITE
Benisouef
Ibrahimia Canal
The Nile
PLATTE RIVER
Minieh
Yusef Canal
Assiut
DAM
Sohagia Canal
Sohag
Girgeh
Nagi Hamadi
NORTH PLATTE R.
SOUTH PLATTE R.
The Nile
Luxor
Esneh
Edfu
DENVER
First Cataract
DAM
Assuan
Shellal
SOUTH DAKOTA
LYBIAN DESERT
NEBRASKA
DESERT
ARABIAN
KANSAS
WYOMING
COLORADO
Scale of miles
0 5 10 20 40 80 120 160

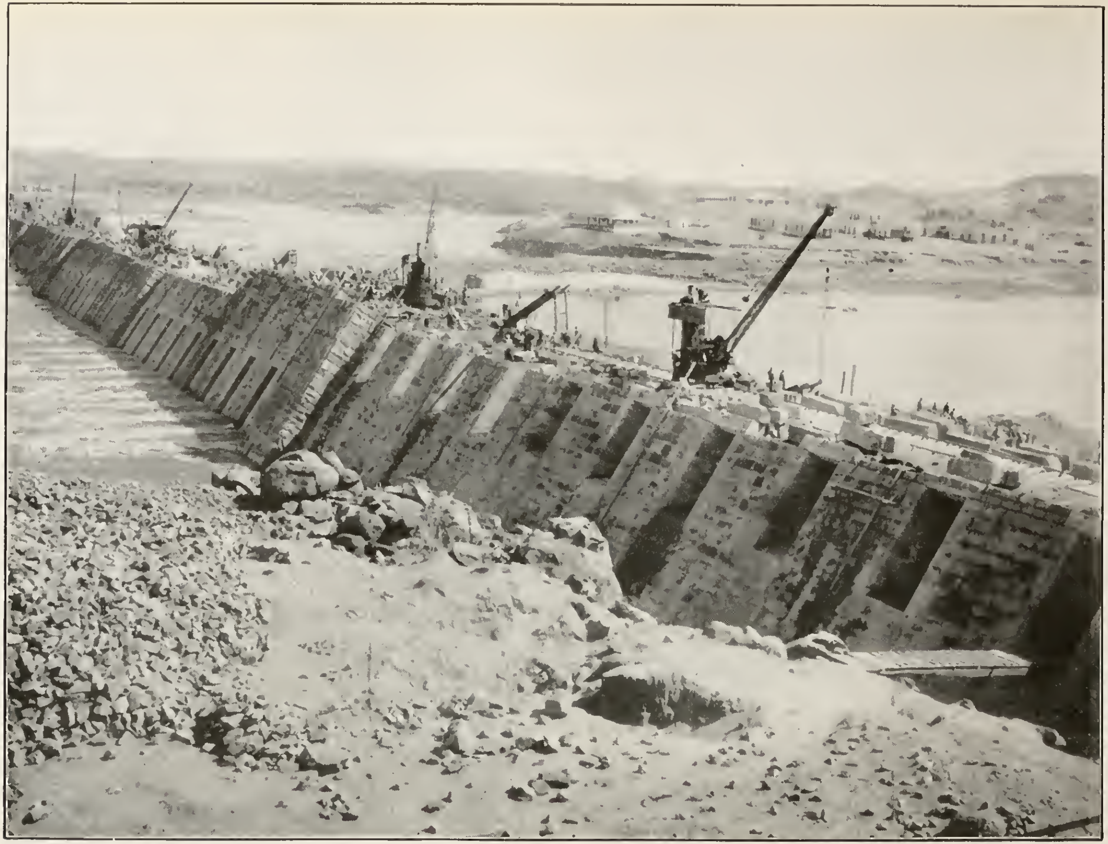
MAP COMPARING THE NILE VALLEY WITH THAT OF THE PLATTE RIVER.


SCALE IN FEET.
0 250 500 1000 2000 3000
East Channel
Assuan Dam
PRELIMINARY SURVEY
HAB'S
MOHAM-MED ALI
NAVIGABLE CHANNEL
ERNAB
SHELLAL
SALIB
AWAD
BIGEH
HESSEH
PHILAE
SHELLAL
EGYPTIAN RAILWAY
HILLS
WESTERN DESERT HILLS
THE RIVER NILE
EASTERN DESERT

MAP SHOWING THE ASSUAN DAM ACROSS THE NILE.



THE ASSUAN DAM.



WESTERN END OF ASSUAN DAM FROM DOWNSTREAM, JANUARY 7, 1902.

dam will be 65.6 feet when the reservoir is full. The cross section of the dam shown herewith (fig. 8) needs but little explanation. The roadway running along the top of that portion of the dam containing sluiceways is 16.4 feet wide. A large part of the eastern end of the dam, containing no sluiceways, is narrower, and the roadway there is reduced to 9.8 feet. The rubble masonry of the body of the dam is laid in 4 to 1 cement mortar, and the downstream slope is faced with squared rubble laid in the same mortar and pointed in 2 to 1 cement mortar. The upstream slope, being submerged a large part of the year, is faced with squared rubble laid in 2 to 1 cement mortar and pointed in the same. The batir of the lower slope of the dam is 1 to 1½.

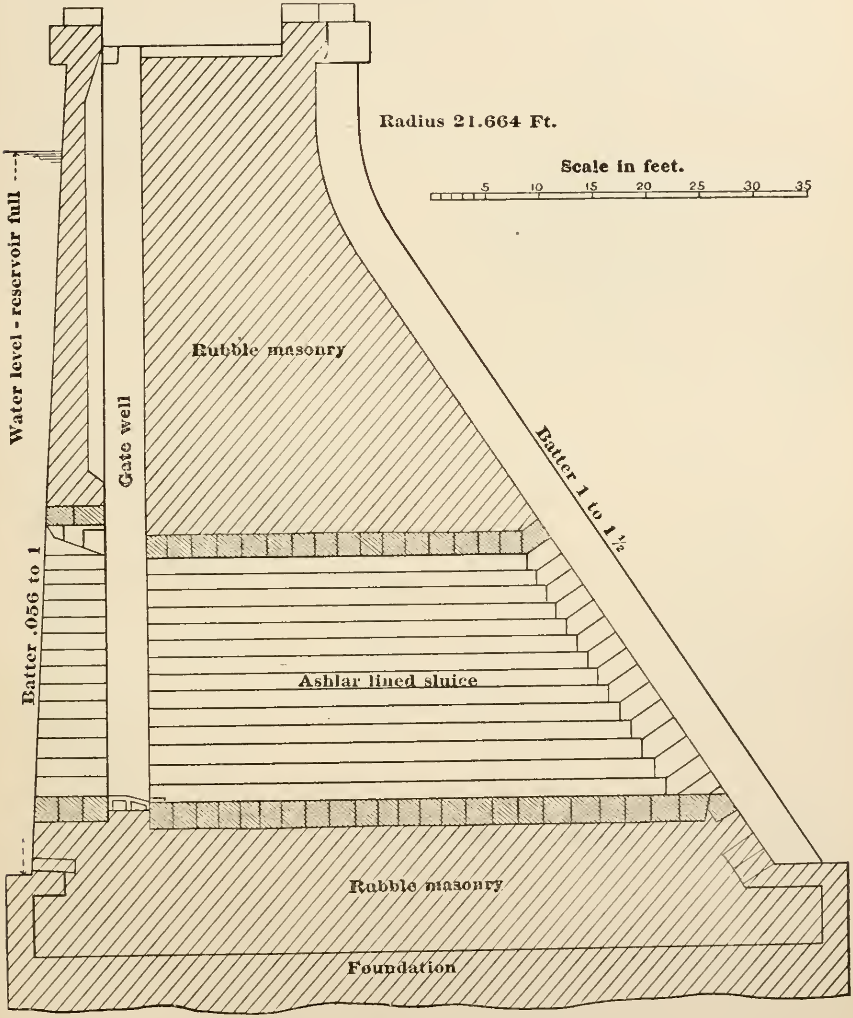

Radius 21.664 Ft.
Scale in feet.
5
10
15
20
25
30
35
Water level - reservoir full
Rubble masonry
Gate well
Batter 1 to 1½
Batter .056 to 1
Ashlar lined sluice
Rubble masonry
Foundation

Fig. 8.—Cross section of Assuan dam.

Buttresses 3.75 feet thick and 26 feet wide are located between each set of 10 sluiceways, or about 240 feet apart. The buttresses were added rather for the sake of appearance than to increase the strength of the wall. The four locks at the western end of the dam are each 260 feet long and 31 feet wide. They will enable small boats to pass at nearly any time during the year.

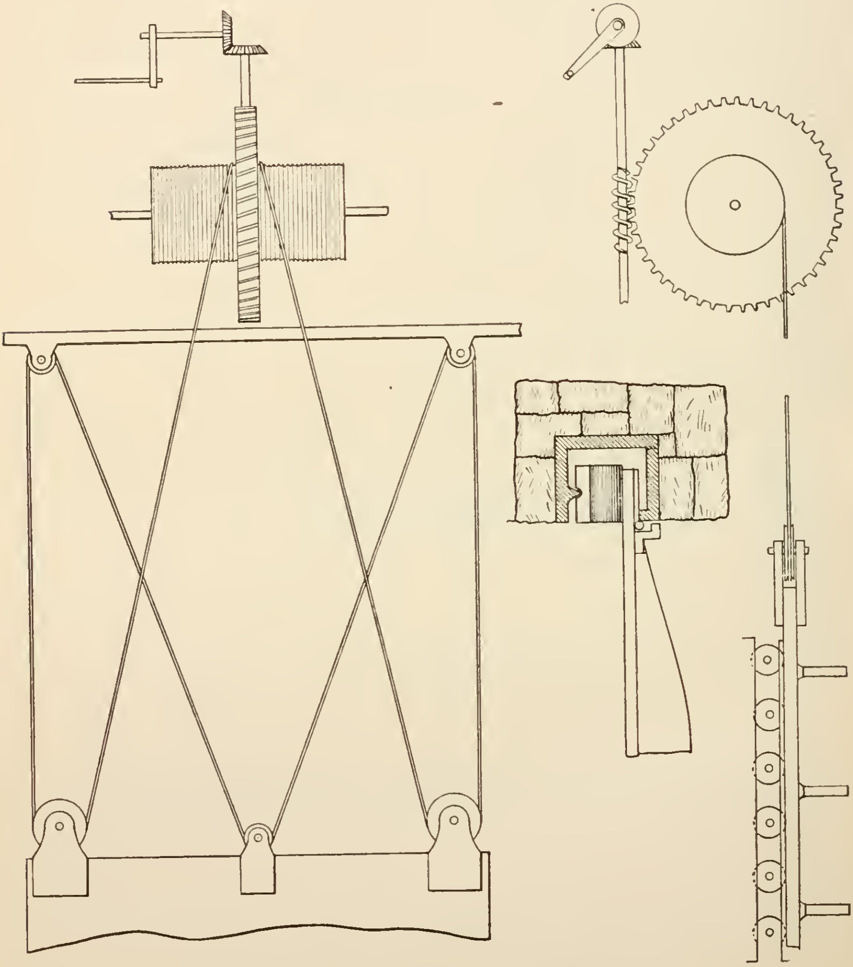


FIG. 9.—Details of apparatus for raising gates. Assuan dam

There are 180 sluiceways through the dam. Of these 65 have been placed with their sills practically on a level with the bed of the river. Forty of these low sluiceways are lined with cast iron (Pl. XXII, fig. 1), all others being lined with ashlar masonry. The cast iron is not considered as durable as the granite, but by employing it the work was much hastened, so that the sluiceways commenced at the end of one high-water season could be finished before the flood again appeared. Seventy-five sluiceways have their sills 14.76 feet above the bed of the river. Of the latter 25 are supplied with roller gates and the remaining 50 have simply sliding gates, to be operated only when the head of water against them is small. Eighteen sluiceways have been placed 27.88 feet and 22 sluiceways 41 feet above the bed of the river. All of the sluiceways except the upper 40 are 6.56 feet wide and 22.96 feet high. The upper sluiceways have the same width but are only one-half as high. The rollers lie between paths on the gates and paths fastened to the masonry of the dam. The gates themselves are built up of steel plates, stiffened by rolled steel joists, which in turn are bolted to the cast-iron roller path beams. The following description of the gates and gearing for raising them has been furnished by Ransomes & Rapier, Limited, the manufacturers:

> The gates are suspended by steel-wire ropes passing around pulleys so as to give 10 parts of rope. The two ends of the rope are wound upon a crab barrel placed at the side of the roadway at the top of the dam. The crab gear is such that one man can operate each gate with the full head of water against it, the gate not being in any way counterbalanced. (Fig. 9.)
>
> Cast-iron grooves are built into the dam in order to provide the necessary space for the gates to work in. These are cast in sections and bolted together in place. A cast-iron sill piece and a cast-iron lintel form the top and bottom of the sluiceway opening. An arched roof casting supports the masonry over the entrance to the culvert in front of the sluiceway.
>
> Owing to the cutting nature of the silt in the Nile water, it has been thought advisable to provide stanching rods on each side of the gate and also in the lintel casting. These rods will make the gates practically water-tight when shut down.
>
> In the case of the 50 sluiceways 14.76 feet above the bed of the river, which are without rollers, the gates slide against the planed faces of the groove castings and are made water-tight against the faces, and also on the sill when the gates are completely lowered. The top is rendered water-tight by an adjustable bar bolted to the gate which lowers onto a projection from the lintel when the gate is in its final position.

The location of the sluiceways on the high level will permit the water of the reservoir to be controlled without its being necessary to manipulate the other gates, which will withstand a pressure of 300 tons when the reservoir is full. Toward the 1st of December of each year the lowest 65 and the 50 ordinary gates 14.76 feet above will be closed. The reservoir will immediately begin to fill, and the 25 sluiceways furnished with Stoney gates will be slowly closed as the discharge of the Nile warrants. It is hoped that in this way the reservoir may be entirely filled without appreciably affecting the flow of the river. The upper gates will be the last to be closed while the reservoir is filling and the first to be opened when the water is turned back into the Nile in May. The sluiceways furnished with Stoney gates will next be gradually opened, and all the gates will be raised by the middle of July, when high water appears. They will remain open until the flood has practically disappeared and comparatively clear water again flows in the Nile.

Work on the foundation and lower parts of the dam had to be prosecuted during low Nile. The numerous channels into which the river is divided at the head of the first cataract favored this work. Temporary dams thrown across one channel turned the water into others, and, by thus changing about, each part of the foundation was completed and put in shape so that the next flood could pass over it without injury. Along the west margin of the river immediately above the dam it was found necessary to resort to riprapping, as the material is rather fine and the current sets in against that bank during high water. The greatest difficulty in the construction of the dam was to find stable material upon which to place the foundation. In one of the channels the partly decomposed granite had to be excavated to a depth of 60 feet below the bed of the river (Pl. XXII, fig. 2), making the total height of the dam at this point over 120 feet. The neighboring country supplied a fine quality of granite in unlimited quantities. The Egyptian Railway connects directly with steamers at Alexandria, and cement was delivered at Shellal, within 2 miles of the dam site. The contractor built light railways from the dam to Shellal and to the quarries. In this way the stone, cement, and other supplies were brought to the point where needed and were lifted direct from the cars to their final positions in the dam. The rubble masonry stone of which the interior of the dam is composed was carried up inclined planes by natives to the masons. The cement mortar for this work was mixed alongside the dam and handled in the same manner. The large dimension stone of which the face of the dam is constructed was cut at the quarry and shipped as needed. The edges of the stone were protected by wooden frames, and other precautions were taken to keep the corners true while the heavy blocks were being handled.

The first cost of the dam was $9,740,000, which, with interest, will be paid in 60 semiannual installments of $382,845.31 each, the first payment to be due July 1, 1903. This makes the final cost of the dam, including interest, $22,970,718.60. The cost of the work, not including the purchase of land which the reservoir covers or the repairs made to the temples of Philae, amounts to $11.26 per acre-foot of capacity. The ultimate cost to the people of Egypt, including interest charges, will be $26.56 per acre-foot. Egypt has also raised $5,746,600 for improving canal systems, especially those of Upper Egypt, so that the water supplied by the reservoir may be distributed.

As the water stored by the reservoir could not serve all the land which might be reclaimed in Egypt, it was decided to furnish water to the areas already under cultivation but which suffer from drought during the months of scarcity. That part of the valley lying between

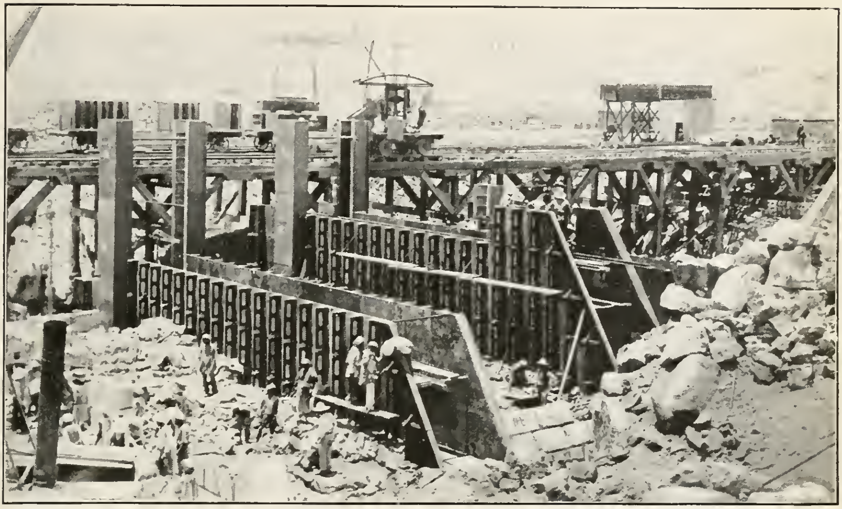


FIG. 1.—CAST-IRON LINING FOR SLUICEWAYS BEING PUT IN PLACE AT THE ASSUAN DAM.

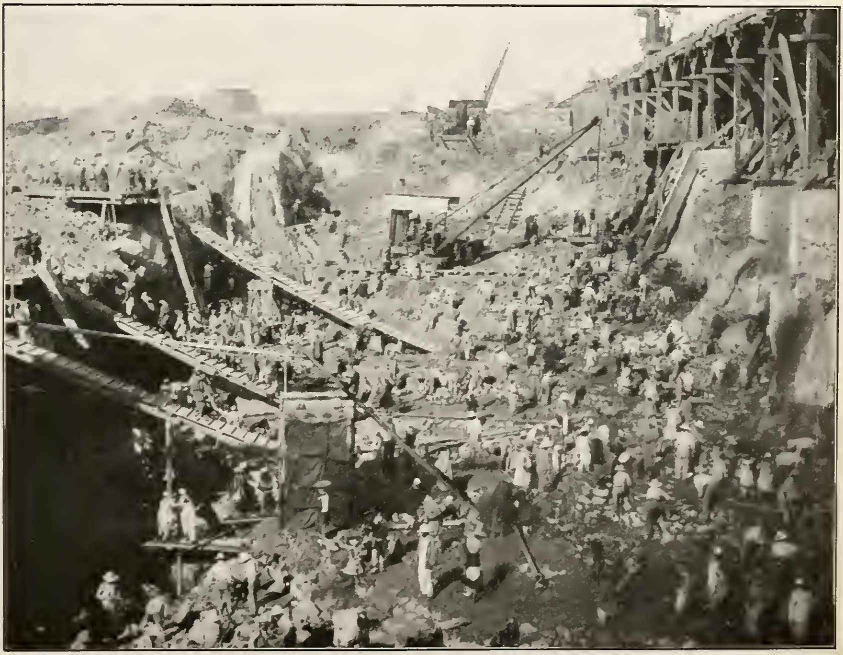


FIG. 2.—DEEP FOUNDATION WORK NEAR WESTERN END OF ASSUAN DAM.

Assuan and Assiut was allotted 137,800 acre-feet. The lands between Assiut and Cairo were allotted 482,400 acre-feet. Gizeh province alone, near Cairo, was allotted 68,900 acre-feet. The territory north of Cairo, principally in the delta, was allotted 243,200 acre-feet. The sum of these figures is 863,400 acre-feet, the estimated capacity of the reservoir.

The engineers have estimated that about 70,000 acres can be irrigated from the reservoir between Assuan and Assiut, giving this area about 2 feet in depth, the water being measured in the reservoir and no allowance made for loss either through evaporation or seepage. One authority states that only one-third of the land is cultivated in any one season, which allows 210,000 acres to be served. It is extremely doubtful if over 70,000 acres can be served in this portion of Egypt during the three seasons of the year. If this area can be changed from flood to perennial irrigation the annual yield of the land will be increased at least $700,000. If 210,000 acres could be brought under perennial irrigation in this part of Upper Egypt, it would mean an increase in the returns to the farmer of about $2,100,000 and in the revenue of the state of about $60,000 per year.

The engineers hope to bring under perennial irrigation 458,000 acres of land lying between Assiut and Cairo. This would make an annual increase in the returns to the farmer of about $5,700,000 and in the revenue of the government of about $950,000. It is estimated that 160,000 acres can be brought under perennial irrigation in Gizeh province alone, yielding an annual increase in agricultural products of nearly $1,000,000 and about $300,000 to the government. By the perennial irrigation of 120,000 acres in the delta it is hoped to increase the annual returns from agriculture there by about $3,000,000 and the revenue through taxation by about $400,000.

In addition to the direct benefits from the reservoir, it is estimated that an average of $1,000,000 will be saved each year on the cotton crop. One year in five the Nile is so low that about $5,000,000 is lost by a failure of a portion of this crop. Besides this, about $5,000,000 will ultimately be realized from the sale of government land brought under perennial irrigation. It is believed that the water stored in the Assuan reservoir will add annually to the wealth of the country a total of $11,000,000. Land which can be perennially irrigated rents about $5 per acre higher than that which depends upon inundation alone. As shown above, the taxes on perennially irrigated land are much higher than on land not so watered. It is expected that the semiannual payments on the reservoir will be met by the increased revenue from the lands deriving benefit from the stored water. In the words of Sir Alfred Milner, "The Egyptian Government is relieved from the difficulty of paying for the works until return is received from them; until, in other words, they pay for themselves."

There is no doubt but that land values have increased greatly since the construction of the reservoir began, and almost any irrigation project in Upper or Lower Egypt has no trouble in securing financial backing. This demand for farming land and the increasing number of capitalists interested in Egyptian agriculture led to a number of inquiries regarding the actual capacity of the reservoir. Engineers were detailed from foreign countries to visit the site of the reservoir and obtain figures to satisfy capitalists that the reservoir would accomplish what it was advertised to do. In this way, and through the annual reports of the government engineers, the Assuan dam has probably become better known throughout the world than any other work of equal importance. However, outside of the surveys in the immediate vicinity of the site of the dam, little has been done to determine the actual capacity of the reservoir. A survey was begun during the winter of 1901–2 to establish the boundary line of the reservoir when full.

THE ASSIUT DAM.

The dam at Assiut was constructed for the purpose of raising the level of the water so that it would flow into large canals supplying water to land on the west side of the river. But one canal leaves the river at the dam. At Dirut, a few miles below Assiut, a wasteway has been built and a number of masonry regulators have been provided. At this place another channel comes in from the river. This latter channel is used only during high Nile. A number of divisions of the Ibraimia Canal at Dirut furnish water for the only perennial irrigation in Upper Egypt until the Assuan reservoir shall have become available. The most important canals below the regulators are the Ibraimia, running parallel with the Nile, and the Yusef, which parallels the Ibraimia for a distance, and ends in the Fayum province.

The Assiut dam resembles the barrage below Cairo somewhat, and, like the barrage, is founded upon soft material, which necessitated a very broad foundation. The general character of the dam is shown in Pl. XXIII. Its total length is 2,646 feet or about half a mile. The height of the roadway above the bed of the river is 44.5 feet. The piers supporting the roadway are 6.56 feet thick. Every ninth pier is 13.1 feet thick. The sluiceways are 16.5 feet wide. The depth to which water will flow through the archways during high Nile is 33.5 feet. Two gates, each 7.8 feet high, were provided for each sluiceway. When these are in position they are capable of increasing the depth of water about 10 feet. The gates are raised by a traveling winch which can be moved to any point along the dam. It is the supposition that the gates will not need to be lowered until the latter part of April each year, and they will be raised before the appearance of high water in July. During high Nile all sediment which may have collected above the dam between April and July will be washed away. A lock has been provided at the western end of the dam.

This design has proved to be the best for dams where the material on which the foundation rests is not solid. It would doubtless give good service in the Platte, Arkansas, and other American rivers where the beds of the streams are similar to that of the Nile north of Assuan.

The Assiut dam cost $1,986,630. The stone was transported from quarries farther up the river and the cement and ironwork were brought from England. The Ibraimia Canal head gate, located on the west side of the river just upstream of the dam, cost $370,000. It is of the same general type as the dam except that it is provided with gates which are designed to withstand the flood water. As reservoir construction progresses on the upper reaches of the Nile, dams similar to the one just completed at Assiut will have to be erected wherever large canals are taken from the river.

DRAINAGE.

In Egypt, as elsewhere, irrigation and drainage go together. The Nile and the canals deposit material along their courses, and, after running in one channel for a long period, this deposit raises the channel above the level of the surrounding country. The water ultimately overflows their banks and runs across the low adjacent country, making for itself shorter routes to the sea. This change in channels has taken place many times since Egyptian history was first recorded.

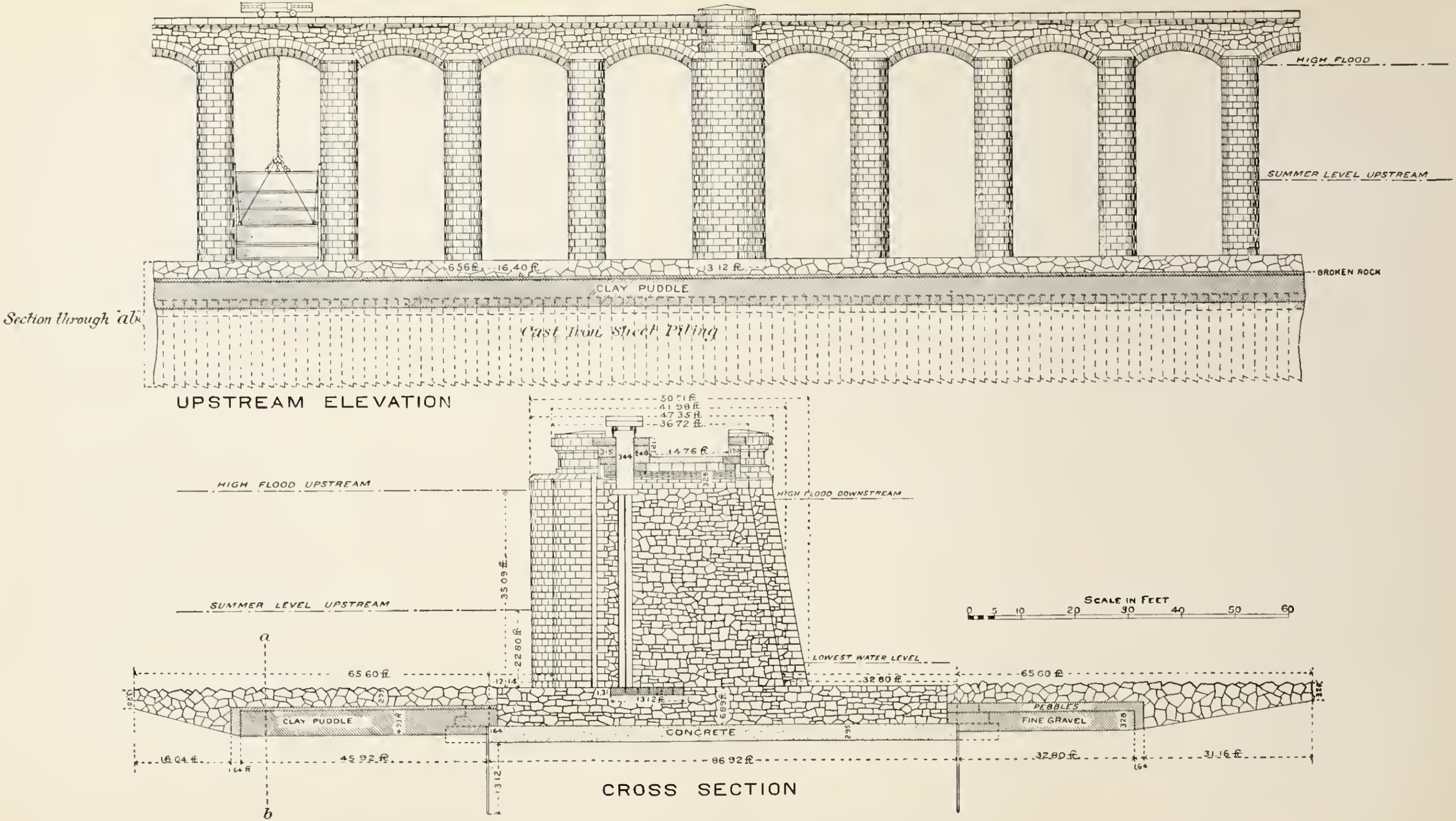
The delta is almost entirely separated from the sea by lakes which are supplied by rainfall, by water escaping from the river, by water from the canals, and by drainage from the fields. The boundary between these lakes and the sea is maintained by wave action of the Mediterranean. The process of draining them would be comparatively simple were it not that in some cases their surfaces are below sea level. Before perennial irrigation was generally extended throughout the delta, evaporation alone kept down the level of these lakes and they did not injure the bordering farming lands. Many drains had been dug, however, by the earlier irrigators. During the periods when Egypt was occupied by Turks, Arabians, and others, who paid but little attention to the condition of the farming class or to the success of agriculture, many drains were abandoned, while others were used as canals. Large areas, once good farming lands, reverted to salt marshes. It is with great difficulty that this land is being reclaimed at the present time. Into such a state of disorder had things drifted when the English took charge in 1882 that many of these early drains were used for canals and canals for drains. Many thousand acres which had previously been agricultural land reverted to the original swampy condition. These are being slowly reclaimed.

Immense pumping plants have been installed to remove the water from the surface, and drains have been dug. The surface of the ground is pulverized before fresh water is applied. After the water has dissolved some of the salts it is allowed to flow away. That which is absorbed by the soil reaches the drains and runs away by gravity or is lifted by pumps. This is an expensive and tedious process, but as soon as a portion of the salts are removed rice can be grown, and by careful use of the water the land continues to improve in quality. Much land has been thus treated and is now growing cotton and the more valuable crops of Egypt.

Since the occupation of the English $5,000,000 or $6,000,000 have been spent in drainage work. After the barrage was put in condition for service perennial irrigation in the delta was greatly stimulated, and it became necessary to provide for removing the added volume of water drained from the fields. Much of this water ran into channels tributary to the lakes. (Pl. XXIV.) The level of these gradually rose and threatened large areas of adjoining farming lands. Some of the lakes were drained by constructing simple works which permitted them to flow into the sea whenever there was sufficient difference in level. Lake Edku belongs to this class.

Lake Mareotis, near Alexandria, has probably given the most trouble. Its surface varies from 6½ to 11 feet below the sea level. Unless it can be maintained at least 8 feet below sea level large areas of adjoining lands already drained revert to their original condition. Until 1892 evaporation kept the level of the lake at a satisfactory height and pumping was not practiced. A pumping plant was installed in the winter of 1892–93, but, in spite of the fact that it discharged 200 cubic feet per second, the level of the lake was higher the following year than it had been for ten years before. This rise is attributed to an increased rainfall as well as to the increased volume of water from the irrigated lands. Soon after the installation of the first pumps others were added, until now the plant has a capacity of 1,200 cubic feet per second. The pumps are of the centrifugal pattern and are required to raise the water only about 10 feet. They operate from November until the following May or June. The cost of pumping is about 20 cents per acre-foot, or about 60 cents per 1,000,000 gallons.

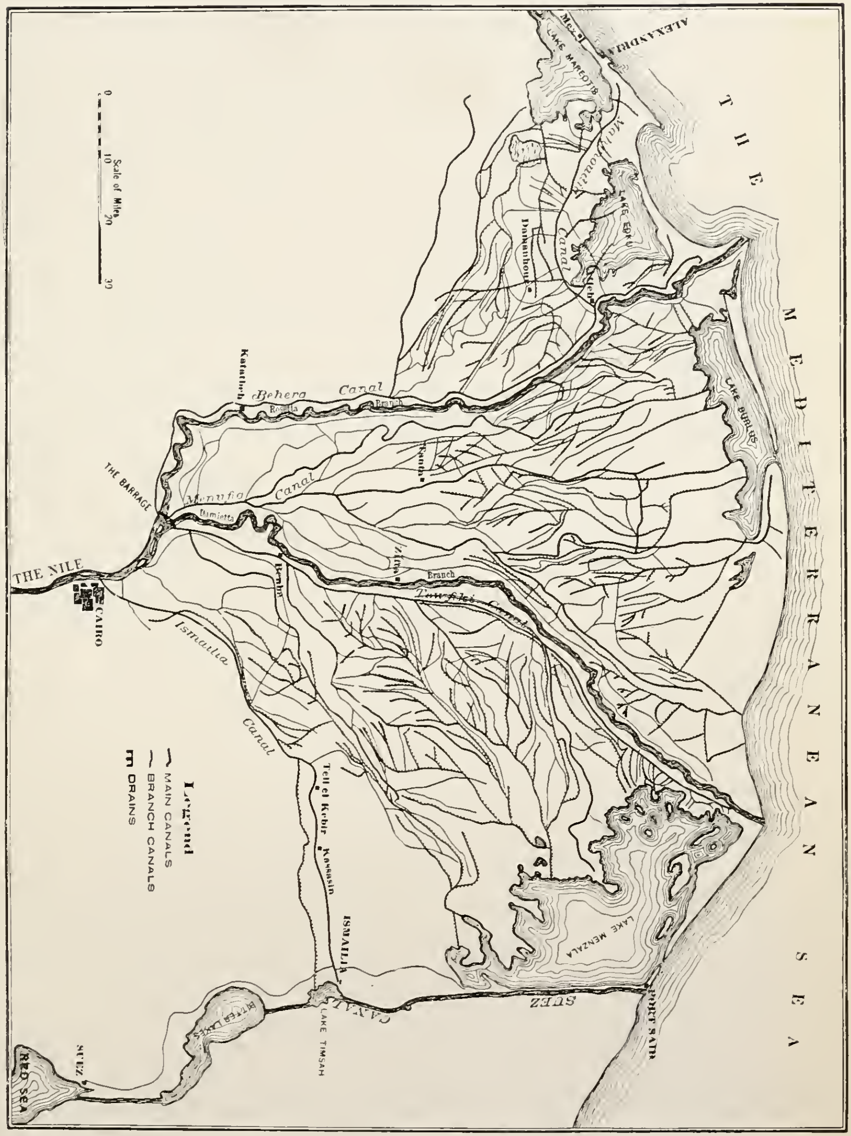
The government owns two pumping plants besides the one at Lake Mareotis. One of these is for draining the Wady Tumilat, a narrow strip of land in a gap in the Arabian desert northeast of Cairo, where a considerable area has been injured by infiltration from the Ismailia Canal. The station is located at Kassasin. The other station, located at Atfeh and previously referred to, pumps water from the Nile into the Mahmoudia Canal.


HIGH FLOOD
SUMMER LEVEL UPSTREAM
6.56 ft
16.40 ft
13.12 ft
BROKEN ROCK
CLAY PUDDLE
Section through "ab"
Cast Iron Sheet Piling
50.51 ft
41.98 ft
47.35 ft
36.72 ft
3.15
3.44
2.46
1.21
14.76 ft
1.90
3.28
HIGH FLOOD UPSTREAM
HIGH FLOOD DOWNSTREAM
35.09 ft
SUMMER LEVEL UPSTREAM
22.80 ft
LOWEST WATER LEVEL
a
b
65.60 ft
12.14
32.80 ft
65.60 ft
3.28
2.95
1.31
13.12 ft
6.89 ft
.93 ft
CLAY PUDDLE
1.64
CONCRETE
2.95
PEBBLES
FINE GRAVEL
3.28
3.28
16.04 ft
1.64 ft
45.92 ft
86.92 ft
32.80 ft
1.64
31.16 ft
13.12
Scale in Feet
0
5
10
20
30
40
50
60

UPSTREAM ELEVATION

CROSS SECTION

DIVERSION DAM ACROSS THE NILE AT ASSIUT.


ALEXANDRIA
Mex
LAKE MAREOTIS
THE MEDITERRANEAN SEA
Mahmoudieh Canal
LAKE EDKU
Damanhour
Rosetta Branch
Behera Canal
Kafatheh
LAKE BURLUS
Tantah
Menufia Canal
Damietta Branch
THE BARRAGE
THE NILE
CAIRO
Zifta
Benha
Tewfiki Canal
Ismailia Canal
Tell el Kebir
Kassasin
ISMAILIA
LAKE MENZALA
PORT SAID
SUEZ CANAL
LAKE TIMSAH
BITTER LAKES
SUEZ
RED SEA
Scale of Miles
0
10
20
30
Legend
MAIN CANALS
BRANCH CANALS
DRAINS

MAP OF LOWER EGYPT, SHOWING PRINCIPAL CANALS AND DRAINS.

LAWS AND REGULATIONS.

CONDITIONS TO BE CONSIDERED.

Egypt was the granary of the world four thousand years ago, and it is natural to look to such a country for model irrigation laws. Unfortunately irrigation in Egypt has developed under conditions different from those of any other country. The character of the Nile flood is such that until perennial irrigation was introduced there was no need of laws and regulations. Beyond some recent reforms therefore, the irrigation code of Egypt is as inapplicable to American conditions as are the sakiyeh and the wooden plow. While the present irrigation law of Egypt provides that certain canals, drains, and other improvements are the property of the government, the rights of neither the state nor the irrigator in the water of the Nile are defined. There are no special regulations regarding the use or the distribution of water, and no legal limit is placed on the volume applied to the fields. Measuring flumes and weirs are unknown. A reform is slowly being brought about through the gradual regulation of the capacity of the lifting devices, but it will be years before these furnish water in ratio to the area of the land irrigated. When one of these raising devices has to be replaced by a new one, or an altogether new plant is installed, the government prescribes the size of the pump, and in this way limits to some extent the volume of water furnished to the lands. Many large pumping plants have been installed, which will for years continue in use practically as they are to-day. Nearly all of these furnish water in excess of the quantity actually needed. The native farmer generally raises water by some of the ancient devices, and hence it is that he suffers by the introduction of the large pumping plants which rapidly deplete the water supply.

AUTHORITY OF OFFICIALS.

To enable the positions of the Egyptian irrigation officers to be understood it will be necessary to describe briefly the character of the government at the present time, treating only incidentally the complex foreign relations which have been entered into during the past thirty years. Egypt is divided into fourteen provinces; six of these are in the delta and eight in Upper Egypt. The Fayum is one of the latter, and includes two oases in the desert. Two oases are also included in the province of Assuit. Egypt, as a whole, may be compared to one of our smaller States, and the provinces with our counties. The accompanying map shows the location of each of these provinces and also the irrigation circles or districts. (Pl. I.)

The chief officer of each province is the governor. Under him is the council, which is made up of the vice-governor, the tax gatherer, a clerk, an accountant, a superintendent of police, a supervisor of canals and public works, a head physician, and a supreme judge, who is a representative of the Mohammedan Church and is the authority on religious affairs. Some of the larger towns have independent governments similar to that of the provinces. Each province is divided into districts, over each of which there is a chief officer who is at all times under the orders of the governor of the province. Under these district officers come the sheiks, who are mayors or local magistrates. The larger towns are also divided into precincts, each of which has its magistrate.

In theory the government of Egypt is one of the most complicated in the world; in practice it is comparatively simple. The British minister plenipotentiary and his advisers are the real government. Native Egyptian officers have certain duties, but the English have all the authority. The theoretical heads of the government are the Sultan of Turkey, represented by the khedive; a number of foreign nations, including Great Britain; while the third and most important is Great Britain alone. The government therefore has three heads, only one of which is authoritative. Apparently the khedive is an absolute monarch; in reality he has no authority except such influence as the local representative of the Mohammedan Church in a Mohammedan country would naturally have. Then again, Egypt is a dependency of Turkey and pays $2,262,000 annually in tribute to Turkey, receiving nothing in return. While the Sultan has no political influence in Egypt, he is at the head of the Mohammedan Church. The finances of Egypt are largely controlled by a commission made up of representatives from foreign countries. Foreign judges sit in the mixed tribunals. Criminal suits against foreigners are tried in consular courts of the nationality of the accused, or he is returned to his own country and tried by a competent court there.

A decree of the khedive has no weight unless sanctioned by the British minister; neither can he veto a measure against the advice of that official. Before any measure can become a law it is prepared in the shape of a decree by one of the seven ministers. The minister of the interior is the prime minister and president of the council of ministers. Under him are the minister of public works, the minister of public instruction, the minister of foreign affairs, the minister of finance, the minister of justice, and the minister of war and marine. These ministers are native Egyptians, but the undersecretaries are British and control the policy of each department. These undersecretaries are advised by the British minister, and in this way his influence is felt through every department of the government. After a decree has been prepared by one of the ministers it is submitted to the council of ministers and the British financial adviser, or his delegate, who has a right to attend the meetings of the council. Any measure which provides for a change in the financial affairs of the government this official has a right to veto. His power in this particular is absolute, and he is not required to give a reason for his actions. The business affairs between Egypt and Turkey are conducted by the prime minister and a special commissioner from Turkey.

Egypt has no popular government. No elections are held; hence the public takes little interest in the affairs of the government. In fact, public sentiment does not exist. Under the organic law of May, 1883, a representative assembly is provided for, but the same act contains so many restrictions that the functions of this body are entirely advisory. Some of the larger towns of Egypt and the fourteen provinces have something like local government, but, owing to the complicated nature of the control of Egypt, privileges of this kind can not be much extended. About all the advantage enjoyed by the provinces or these cities is that their local councils or assemblies may discuss measures which affect their communities. The council of ministers considers their recommendations when it meets, and in this way becomes acquainted with public needs as nearly as the council can interpret them.

The legislative council, composed of thirty members, meets at Cairo about once a month. Fourteen of the members of this council are named by the government, and the government reserves the right to delegate any other official to attend its meetings. Nothing can originate in this council, but it can examine the estimate of expenditures and discuss decrees which affect internal administration. The government is not required to accept amendments made by the legislative council, but the reasons for rejecting any amendment must be submitted in writing.

In addition to the legislative council, there is a body known as the "general assembly." It is composed of the ministers of state, the thirty members of the legislative council, and forty-six delegates, of whom thirty-five are chosen from the fourteen provincial assemblies and eleven are selected by the government. Before this body can meet the khedive must issue a decree calling for a session. The assembly should convene every two years; in practice its sessions are irregular, and when it meets its sittings are short and the business coming before it is of minor importance. It has no legislative privileges, but can veto any measures relating to taxation. No new taxes can be imposed without obtaining the consent of the general assembly. In fact, this is its only real power.

Regardless of the seemingly complicated nature of the government, the lawmaking power is quite simple. After the council of ministers has approved a decree it is transmitted to the khedive. It makes but little difference whether he signs it or not. His power of veto can not be exercised when it conflicts with the advice of the British minister. As these acts or decrees originate with the ministers, and the policies of each minister are dictated by a British undersecretary, it is but seldom that measures are introduced that have not the indorsement of the English.

The irrigation officials are under the minister of public works and include an inspector-general of irrigation, one inspector of irrigation for Upper Egypt and one for Lower Egypt, and an inspector-general of reservoirs. These officials are all English, and all but the inspector-general of reservoirs have permanent positions, and his will doubtless last until reservoir construction has been completed. In the same rank with these officials stand six heads of the irrigation administration, who are native Egyptians. The head of the technical service is an Egyptian, and this branch is closely allied with the irrigation administration. To him are referred all technical questions relative to the issuance of licenses for pumps and other lifting devices. The survey department is in a way connected with the irrigation work. It has an English director. Two other departments, one dealing with towns and buildings and the other with antiquities, have but little to do with the irrigation administration. The two inspectors for Upper and Lower Egypt and the heads of the drawing and mapping divisions have their offices at Cairo.

Egypt is divided into irrigation districts, which, for convenience, are known as circles, and each circle has an inspector. The inspectors of the first and second circles have their offices at Cairo, the inspector of the third circle is at Alexandria, of the fourth at Mineh, of the fifth at Keneh, and of the sixth at Sohag. The directors of the first, third, and fourth circles are English. The remaining three are Egyptian. The inspectors of the circles have immediate charge of cleaning canals, building smaller diversion works, repairing masonry structures, keeping gauge heights on the Nile and on canals, and dividing the water among canals in accordance with the area under each or as the inspector-general may otherwise instruct. Under these men are other officials, most of whom are natives, who travel about and see that the instructions of the inspectors of the circles are carried out. Ordinarily the responsibility of the engineer ends when the water is turned into the canals.

Every canal which serves more than two villages is held to be public, and comes directly under the irrigation administration. There is nothing in the law which requires a certain discharge to be supplied in the canal during any part of the year. There is nothing to prevent an irrigation official closing one canal or all at his pleasure. When water is supplied the canal the irrigator can use as much as he can lift and convey to his land. What he does not need he is free to waste. If the canal supplies too much water and floods adjoining land, or if it fails to supply enough to irrigate the farms depending on it, the irrigator has no recourse except to apply for a remission of a part or all of the tax ordinarily paid.

During the seasons of scarcity time rotations are enforced, over which the engineer has almost absolute control. The purpose of the administration is rather to save the more valuable crops than to protect the irrigators uniformly. This insures a maximum return to the treasury through taxation, but seldom affords an impartial and equitable division of the water. For instance, during some seasons rotations occur every four days; that is, irrigators are allowed to use the water a certain length of time and then be deprived of it for four days. During the warm seasons of the year, in June and July, four days of drought is sufficient to kill rice. The fellah who has planted this crop is the sufferer, and, although his taxes are remitted, he has no income from his land and must earn his living in some other way. It has been found necessary to modify the rotations under some of the longer canals because it often occurs that the water never reaches the lower end of a canal. Usually when water is turned into a canal it is allowed to run for a day before any one is permitted to divert it. In this way it will run a considerable distance before the volume is diminished to any great extent.

CAUSES OF LITIGATION.

Owing to the fact that the government controls the diversion and division of water there is no litigation between irrigators as to water rights. Cases are occasionally brought against the government because the water supply is short or because the size of the pump the engineers have permitted to be installed does not suffice for the irrigation of the lands it was intended to serve. These cases are becoming rare, as the engineers can generally show that the water was distributed as generously as the supply furnished by the river would warrant and that the volume made available by pumping, if properly used and distributed among the irrigators, would have sufficed for all.

Such suits, if the amount of money involved is small, go first before the native courts, where, at present, a government officer is usually looked upon with suspicion. For this reason an engineer outside of the government service can often greatly annoy the administration by making adverse reports or giving testimony in contradiction to that presented by the government engineers. As the irrigation cases in the courts are nearly all small and relate generally to rights of way and similar questions, the engineers have never had to give them much attention, and as the English have slowly instituted reforms in the court proceedings, just decrees and decisions are now the rule rather than the exception. The Egyptian engineers are also favored by the absence of any specific laws or regulations which would limit them to certain prescribed duties. With the power behind them which secured them their positions in the first place, they are enabled to take whatever decisive action is necessary and to institute such reforms as, in their judgment, are plainly necessary.

Another question which often leads to lawsuit against the government is the remission of taxes on the irrigated land or the reduction of taxes on the lands where the water has to be pumped. For instance, during the summer of 1901, only 38 acres out of a 50-acre farm were covered during the Nile flow, leaving 12 acres to be watered by pumping. As the owner failed to notify the government at the time that the water was not high enough to irrigate all of his land, he was taxed for the entire 50 acres as though it had all received the benefit of the high Nile. The government taxes on land which has to be irrigated by pumped water are only half as much as where the land is flooded. A suit of this kind is often expensive, and the testimony is generally quite voluminous. If a native brings the suit, and the area is small, involving a loss of less than $500, the case goes to a native court. If the land belongs to a foreigner the case goes to the mixed tribunals. In the former court the proceedings are in Arabic, and the records are published in Arabic and English. In the mixed tribunals the proceedings are generally in English, French, or Italian, and the proceedings are always published in French or Italian. If an appeal is taken from the decision of the mixed tribunals, the case goes to the court of appeals at Alexandria, where the proceedings are in French and are published in French.

When Mohammed Ali undertook the execution of the perennial irrigation works in Egypt, he carried on the reform as though he were the proprietor of all the land and water in Egypt. He fixed the rate of taxation, hired engineers to design the irrigation works and superintend the construction of the same. Where labor was wanted, he forced the fellaheen to leave their farms, either to excavate the canals or to work on the numerous irrigation structures connected therewith. The Egyptian farmer has long been used to this kind of treatment. In fact, he has never seen anything else until within the last fifty years, and it will take him a long time to entirely recover, even if the government makes it possible for him to do so. It is not surprising that a wise irrigation code has not developed in Egypt, when all of these conditions are considered. In a country where land titles were unknown, it would not be presumed that the rights of an irrigator would be recognized or protected.

Mohammed Ali, while not granting permanent title to agricultural land, instituted many reforms. Among these was the distribution of from 2½ to 5 or 6 acres of land to each person. This was made quite early in his reign, and in 1842 he permitted the holders to dispose of their land as they pleased. At no time, however, did they hold any actual title to the land they farmed. Together with the lack of titles and the weight of taxation, the fellaheen have in many cases been forced to dispose of their land, and much of this is now included in the large estates.

Under Ismail large tracts were confiscated by the government. About a fifth of the agricultural area of Egypt is either directly or indirectly under the control of the state at the present time. Something over 500,000 acres have been in charge of the Daira Sanieh, which company has a contract with the government that stipulates that the land shall bring a fixed price when disposed of. About 96 per cent of the tillable land in this area is rented in small parcels to the peasantry. They pay on an average about $20 per acre per year in rentals. The land remaining unsold in 1905 reverts to the government. The land sold prior to that date goes largely to the small farmer, and whatever profit is made recompenses the company for its bringing the land under irrigation and placing it on the market. In this way a large area will return again to the fellaheen. About 440,000 acres are still included in the domains of the state. One hundred thousand acres of this land are located in Upper Egypt and the remainder in Lower Egypt. Probably 80,000 acres of this land will never be cultivated.

While Ismail Pasha inflicted many wrongs upon Egypt, one of his acts has resulted in benefit to the people. He was indirectly responsible for establishing the first titles to farming land in Egypt. He taxed the people to the limit, borrowed money with whatever credit he had, and without credit when this was exhausted. In an attempt to secure ready money he finally issued a decree providing that all persons who paid their taxes six years in advance would be given permanent titles to their land. Those who could afford to do so took advantage of this offer, and the titles thus obtained have since been recognized. The law was repealed in 1880, however, because it was not as good a financial measure as it had promised to be.

IRRIGATION AND DRAINAGE LAWS.

When the English engineers first undertook a study of Egyptian irrigation it was found that the law of Egypt was fragmentary and it was difficult for them to tell what provisions were in force. As early as December, 1885, the public works ministry issued regulations defining the respective powers of the governors of provinces and the inspectors of irrigation. These regulations (see p. 83) are still in force and are among the first reforms in irrigation law.

Such duties as the law of Egypt prescribes for the officers in charge of the division of water are not clearly defined. The relative powers of the director-general of irrigation and the inspector of Upper and Lower Egypt and the subordinates are not set forth. This leaves the authority wholly with the director-general and enables him to take such steps as may in his judgment be necessary during times of emergency. There is nothing in the law which would govern the acts of the officials during times when rotations are necessary. They are not authorized to distribute the water so as to save any particular crop or to favor any locality or person. When a scarcity of water exists the relations between the governors of the provinces as prescribed by law have but little force. Water is distributed according to plans originating in Cairo and carried into effect by the inspectors for Upper and Lower Egypt and their subordinates. Even during such periods no attention is given to the necessities of the irrigators. Canals supplying water to the most valuable crops receive water in rotation, and each irrigator may raise and use as much as he can while there is water in his canal. If waste occurs, but little attention is paid to it. Under this system one canal may be favored this year and another the year following, depending upon which serves for the irrigation of the more valuable crops. The irrigator, it will be seen, has no recourse should his water supply fail. An appeal to the officers of the province might be heeded, but the engineers of the government would not be constrained to alter their plan of distribution.

It will be seen that the operation of such a system places all responsibility on the government. The defect in the system is that the people are not considered as having any rights, but are treated solely as a revenue-producing body, and a farmer who receives water one year has no assurance that he will be served the next year. There can be no stability in land values and no justice in the operation of a land-tax law under such conditions, although the rate of taxation is, to some extent, regulated by the value of the farm products. It seems that the time must come when the distribution will be fixed permanently. Under such a system the farmer would know, as soon as the stage of the river was reported from Assuan, as to whether he would be supplied or not. The completion of the reservoir system will do much toward settling this question, but it will be fifteen or twenty years before the farmers of Egypt can expect to receive entire relief.

The regulation of December, 1885 (see p. 83), fixes the relation between the governors of provinces and the irrigation officials. Section 1 provides that: "It is the duty of the governor to see that a just distribution of the water is made in the various districts composing his province." This is followed by a sentence which reduces his authority to reporting the needs of irrigators to the irrigation inspectors and listening to the complaints of the village chiefs.

The second section requires the inspectors to report to the governors, as well as to the minister of public works, should it be impossible to satisfy all demands for water.

Section 3 defines the duties and powers of the inspectors controlling the distribution of water and permits no gate to be operated without written orders from them. If the governor does not approve of the action of the inspector or engineer he may appeal to the minister of the interior, but the order of the inspector will stand until countermanded by the higher official. During high Nile, or whenever work is necessary to avoid disaster, the orders of the governor supersede those of the engineer, and the engineer gives notice that discord exists, when the governor becomes responsible for what takes place. As the work is largely of an engineering character, it is only in rare cases that the governor prefers to take charge in the field.

The classification of improvement works provided for in articles 9 and 10 is worthy of notice. The governor has nothing to do with awarding the contracts for excavation requiring the services of more than 1,000 men, masonry work costing more than $974, or work where machinery is necessary. The law provides, however, that the governor shall be notified as to the character of the contract, and he has the privilege of reporting any failure on the part of the contractor to the engineer. In smaller improvement works the governor and engineer work together, selecting the contractor and supervising the work, the governor being the judge as to the reliability of bidders.

This regulation not only prepared the way for the irrigation laws that were to follow, but made it much easier to introduce reform measures regarding the corvée. As soon as the contractors on large enterprises were brought directly under the minister of public works and his assistants a solution of some of the labor problems could be undertaken. It was supposed at the time the regulation went into force that the use of machinery would go a long way toward reducing the labor of the corvée, but experience has not proven this to be the case.

While the need of better laws was evident to the engineers under the Egyptian Government, it was impossible or impracticable to bring about the enactment of a fairly comprehensive code until 1894.

The first article of this decree (see p. 85) defines a canal as a waterway which supplies more than two villages. These are public and are maintained by the government. A ditch is a channel which provides water for one or two villages, or for land belonging to one person or family, even if located in several villages. These latter are private property and must be maintained by those deriving benefit therefrom, but the government may clean them should the owners neglect to do so and tax the cost against the owners. As the number of irrigators under any canal increase, the necessity for government control in this respect evidently becomes greater.

Drains are classified in much the same manner as are ditches and canals. If a drain serves but one or two villages it is considered as a private work, unless it serves more than 2,000 acres. In the latter case or when it serves more than two villages it is considered public. Drains are maintained under the same regulation as are canals and ditches. This is probably due to the difficulty of distributing the work of maintenance fairly among the owners. A provision has therefore been inserted in article 2 under which any ditch may be considered as public property should it serve for the irrigation of as much as 1.000 acres belonging to several persons.

Embankments and levees for protecting the country against the flood of the Nile are considered public property. These are maintained by the government.

Article 6 and many others of this decree have been recommended by the inspectors. During the first ten or twelve years of English occupation the provisions of section 6 would have been of great benefit in many cases. It stipulates that the owners of lands through which a public ditch passes can not destroy the same in order to make the land tillable without the written consent of the persons depending on the canal.

If it is necessary to close a canal for repairs or in order to give the water to others who are in greater need, irrigators can collect no indemnity from the government for the loss occasioned by a lack of water.

Article 8 is particularly interesting to those who have made a study of public supervision of water. One of the first necessities under such supervision is that the State shall have authority to limit the diversion of water when further canal construction may injure users already on the ground.' Even in Egypt, where the Nile furnishes an almost unlimited supply during a large portion of the year, it has been found necessary to limit construction work where the rights of others are threatened. The intent of the law throughout is to distribute the cost of irrigation works in proportion to the benefits received by each user. This is well illustrated in the article under discussion. If a permit is granted authorizing the construction of a ditch others may use the works, providing they pay toward the cost of construction and maintenance in proportion to the benefits they are to receive.

The procedure for condemning lands for right of way for canals and ditches is set forth in article 9.

The value of farming land in Egypt is well illustrated by the provision of article 10 relating to enlargements of existing ditches. A right of way does not give the canal owners title to land lying on either side of the channel; hence when enlargement is contemplated it is necessary to condemn the additional land that must be used for the enlargement.

Article 12 relates to the diversion of water from canals. No lateral can be taken from a canal without the approval of the inspector, but if it is desired to install a sakiyeh the chief engineer decides the matter, and also designates the location of the lateral or sakiyeh. Permits are applied for and granted under provisions of the decree of March 8, 1881.

Where a ditch, canal, or drain becomes a detriment to agriculture in any way, it may be filled in at the request of the owners of adjoining property, providing another watercourse can be used in its place without injuring other lands.

Article 14 illustrated the necessity of limiting the size of ditches and head gates to the dimensions necessary for serving the lands irrigated therefrom. If water were measured in Egypt as it is in some of the irrigated districts of the United States there would be no necessity for such restrictions. The time and money spent in changing the dimensions of canals and masonry regulating works would go far toward maintaining an adequate system of discharge measurements.

The close relation between irrigation and drainage is evident throughout the decree. Article 15 sets forth the procedure for locating a drain when the party to be benefited and the party through whose land the drain is to pass fail to come to an understanding.

The provision of article 19 is interesting when compared with the laws of some of the Western States. The article relates to the breaking of ditch banks, embankments, etc., and prescribes that if such an offense is committed complaint is made to the governor, who refers the matter to the inspector or chief engineer, who makes an examination of the ground, after having given at least fourteen days' notice of the examination. If the accused is found guilty he is required to restore the property or bear the expense of such work as may be necessary to restore it. In some of our States the fact that the water has been used is prima facia evidence that a ditch bank has been cut or a head gate has been tampered with. No notice is necessary and the water commissioner has police authority and can arrest the offender at once.

Another example illustrates how slowly the law is carried into effect in Egypt. If in the judgment of the engineer a small gate needs repairs, forty days' notice must be given the interested parties, that they may remedy it. If the work is not accomplished in the time, another period of forty days is allowed. If the parties still fail to perform the work the government has it done at the expense of the owners.

The decree does not define the rights of irrigators, the unit of measurement, or the basis upon which the water shall be divided among claimants, while other details of seeming less importance to us have been fully set forth.

The Egyptian government can compel the owner of land through which a canal runs to remove trees which are found to interfere with the full flow of water in the canal. It permits cultivation of a canal and its banks under certain restrictions, but assumes no responsibility and no claim can be brought against it should the crops be lost or damaged. If the bank is needed for a highway or other purposes, no procedure is necessary in order to convert it into such, and the farmer who may have planted crops thereon has no recourse.

The articles relating to offenses and prescribing penalties therefor indicate that the engineers who framed the law desired to cover all offenses which had been called to their attention during the previous ten or twelve years. The sections referring to navigation are interesting in so far as they show the importance of the canals to the internal commerce of the country. The decree is given in full in Appendix I.

INSTALLATION OF WATER-RAISING DEVICES.

The decree of March 8, 1881, relative to the installation of machines for raising water, propelled by steam, by a current of water, or by the wind, provides that persons intending to erect such devices shall first apply for a permit, which application is approved or rejected, as the minister of public works or the head of the technical commission may decide. The decree exhibits plainly the attitude of the government toward the user of water. In article 7 it is stated that the approval of the permit carries with it no assurance from the government that water will be supplied the water-raising device. In other words, the government may approve of the installation of a water-raising device on a canal or a branch of the Nile where the water supply is inadequate. The government does not keep itself informed as to the actual discharge of the various waterways which serve the irrigator, nor do the irrigation officials know the capacity of the water-raising devices which are already in operation. After application has been made for a permit to establish a water-raising device one of the officials of the technical department makes an examination of the site where it is proposed to erect the machine. The approval or rejection of the application generally depends upon the report of this officer. When the application is granted a permit is given the applicant. The technical department keeps a supply of the permit blanks, which are bound in book form. The stubs of these blanks contain the permit in full, one side of the sheet being printed in French and the other side in Arabic. The permit itself, which is torn from the stub when the application is approved, is printed in Arabic only. On the reverse of the permit are extracts from the law relating to the installation of machines for raising water. These extracts are taken from the decree of March 8, 1881, and from the decree of April 6, 1881. The form of permit is as follows:

[Form No. 28 T. P.]

MINISTER OF PUBLIC WORKS.
TECHNICAL SERVICE.

No.——.

Regular permit for stationary water-raising device. } Certificate.

Permit No. ——.

NAME OF APPLICANT.

———— ————————

———— ————

CAPACITY OF THE DEVICE.

————————————

————————————

CANAL.

————————————

————

The applicant acknowledges receipt of this permit, together with a copy of the agreements and conditions imposed and of the design.

Cairo, ———— ——, 189—.

Correctly translated.

Cairo, ———— ——, 189—.

Mr. ——— ———, residing at ———, province of ———, is authorized, under the decree of March 8 and the rules of April 6, 1881, relative to water-raising devices, and according to the report of the ——— circle of irrigation, under date of ——— at ——— in ———, province of ———, ——— water-raising device ——— having a capacity of ——— H. P., intended to propel a pump for ——— acres, appurtenant to ———.

The device will be ——— on the ——— according to the design accepted by the applicant and in conformity with the agreements and conditions imposed by the aforesaid report, a copy of which, together with a copy of the design, is attached hereto.

The applicant hereby agrees to abide by the provisions of this permit and also by the instructions that will be given him by the said circle of irrigation, to which this permit must be shown whenever it is requested.

A failure to abide by the conditions and obligations imposed by this permit will release the undersigned from all provisions of this permit, without prejudicing the right which the government reserves to recover damages and reimbursement for expenses incurred. (Article 4 of the decree of March 8, 1881.)

Done at Cairo, ——— ———, 189—.

——— ———,

Chief of Technical Service.

Accepted by the undersigned applicant.
Cairo, ——— ———, 189—.
Approved.
Cairo, ——— ———, 189—.

This permit is of special interest because it is the only form which is recognized by the Egyptian irrigation law. It is the only paper which the government gives an irrigator that recognizes in any way the right to divert and use water. It will be noticed that the permit states the horsepower of the engine which propels the pump and the area of the land proposed to be irrigated. It gives no information regarding the height of the lift, the size of the pump, or the efficiency of the engine.

The decree relating to the installation of water-lifting machinery other than that just described (Appendix II, p. 96) is of special interest, and is of as much importance as any of the laws or regulations governing the use of water. The original decree was issued in 1881, and its provisions were extended in 1890. Any person may still construct and maintain a sakiyeh, a shaduf, or other water-lifting device, except those mentioned in article 1 of the decree of 1881, upon the banks of the Nile. Permission must be obtained from the government before water-lifting devices of any kind may be erected on the banks of canals. As the Nile in many respects differs but little from many of the canals, it is rather strange that this distinction has been made. The levees are more difficult to maintain than are the banks of the canals. Both classes of channels are public property, and most canals, as well as the river, are navigable. Navigation interests, however, are secondary to the needs of the irrigator, as is shown in the inconvenience to which river boatmen are subjected when the entire discharge of the Nile is turned into the large canals in the delta.

DRAINAGE.

The most important drainage work in Egypt is prosecuted by the government. A large part of the main drains and the largest of the pumping plants are therefore under its control. However, there are a number of large holdings, both in the delta and in Upper Egypt, where drainage is necessary. The government has also disposed of a number of tracts under condition that the land be reclaimed and improved so as to yield a revenue to the treasury. There are to-day large areas in the delta which must be drained before as much of Lower Egypt will be cultivated as was farmed before the invasion of the Turks, who permitted the drainage system to deteriorate. The Société du Béhèra, owning lands near Alexandria, has done much in the line of reclamation through drainage. Water is first drawn off by drains or by pumping, and large volumes of fresh water are applied. The surface is kept well cultivated, and gradually the salts are removed to such an extent that rice can be grown. After a few years of rice cultivation more valuable crops can be substituted.

In 1880 there were about 438,000 acres of public land outside of that which had recently been acquired from the khedival estates and put in charge of the Daira Sanieh administration. In 1899 this area had decreased to 210,000 acres, the remainder having been sold to farmers. In 1880 the Daira Sanieh administration controlled about 520,000 acres. In 1899 they had but 302,000 acres remaining.

As a considerable portion of this land required drainage works, it became necessary for the government to enact laws which should place the work partially under government control. It was essential that the government engineers should have authority to direct this reclamation, so that the systems planned and constructed by private parties should supplement rather than interfere with the work already performed by the government. Two decrees have been rendered relating to drainage. One was issued February 21, 1894, the other not until April 26, 1900. The decrees in full are given in Appendix III, p. 99.

THE CORVÉE.

The system of forced and unpaid labor known as the corvée has always been an important factor in all kinds of public construction in Egypt. From building the Pyramids to digging the Suez Canal or the excavation of a small drain, the corvée has been called into service. The labor of the corvée has made Egypt renowned for the products of the soil.

The conditions under which such a system has obtained a foothold in Egypt are largely responsible for the adoption of existing laws and regulations governing the use of water. The difference in the standing of farmers in the United States and in Egypt is almost wholly produced by the operation of the corvée regulations. If we are to make it clear as to why certain laws and practices are particularly well adapted to Egypt and not suited to arid America, the relation between the farmers called into the corvée service and the governing classes should be set forth in some detail.[a] Formerly the corvée was called upon for all kinds of public and private service. At present the system must be considered as an intermediate step between slavery and freedom; many changes for the better have been introduced during the past one hundred years and the future independence of the Egyptian farmer seems assured.

But little has been recorded of the character of the corvée during the early history of Egypt. The immense masonry monuments and temples, as well as the irrigation works which still exists, show how the unpaid labor was utilized. Up to the time of Joseph, some 1750 years B. C., the practice was recognized, and abuses became common after the system of slavery inaugurated under his administration came into full effect. The government owned the people and everything in Egypt from that time until during the early part of the nineteenth century. Some of the recent reports dealing with the use and abuse of this free labor enable us to realize to what extent the fellah has been imposed upon. The following report on forced labor by Mr. H. Villiers Stuart in March, 1883, sets forth the faults in the system at that time:

FORCED LABOR IN THE DELTA.

The complaints made upon this subject are that the apportionment is arbitrary and capricious, poor districts being required to furnish most and wealthy districts fewest laborers.

The richer class of landowners is also entirely exempt. They suggest that in lieu of the present system there should be a proportionate labor rate upon all land alike, instead of throwing the burden upon those least able to bear it.

Every landowner up to 100 acres is liable to forced labor; but he may, if he likes, pay a substitute. Some go and work themselves and some send substitutes. Those who possess no land are not liable.

Those who are liable get no pay whatever for their work; neither does the government provide them with any food whatever. Their friends at home have to send them food from their villages. Usually bread dried in the sun is their sole nourishment. It is sent in sacks, a couple of men from each village being deputed to convey it to the scene of operation. They have also to find their own tools and baskets.

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[a] The system has had great influence on the practice of irrigation and has made necessary the enactment of laws which would not be applicable in countries where the same conditions do not exist. In discussing the customs of the people of Egypt and the irrigation law there in operation, it should be borne in mind that regulations which might operate satisfactorily there would fail in the United States where authority comes from the people.

As a matter of fact, their hands are often their only tools. With these they load the baskets and excavate the soil. No shelter is provided for them at night nor any covering. A certain number of overseers are appointed. These are armed with sticks and superintend the work.

One complaint made universally was that instead of allowing the men of each district to work in their own districts the practice was to send them to distant parts of the province, thus needlessly increasing the difficulty and cost of feeding them and ministering to their wants.

Common sense would seem to suggest employment on the canals and embankments in their own neighborhood by preference, because they would then have a direct personal interest in the work.

They complained that there was much bribery and corruption connected with the appointment of the forced labor, wealthy communities thus purchasing partial exemptions at the expense of those who were too poor to bribe high enough. They said that this was the real reason why the system of letting each district find the labor for its own public works was not adopted, because that would be an obstacle to these corrupt exemptions.

All admitted forced labor to be a necessary institution in Egypt, the maintenance of canals and embankments being of vital importance, but there had been great abuses, and even now they assured me that men were still forced to labor on the estates of the government and of the wealthy pashas, but they said that now those so employed on the privileged lands received pay; previously they received none. This abuse, like many others, has been nominally abolished, but nevertheless continues, the sheiks conniving. Indeed, it is through their instrumentality alone that these abuses are possible.

FORCED LABOR IN UPPER EGYPT.

A cut about 18 feet deep has been made through a conglomerate of sand and gravel; this trench was flanked right and left by high embankments, consisting of the débris excavated.

From the summit of these ridges to the floor of the canal was from 35 to 40 feet deep; along the bottom and on the slopes right and left men swarmed thickly like bees on a honeycomb for a distance of about a mile in length.

The overseer told me that the entire forced labor of the province was concentrated there, 40,000 men in all; that they worked from sunrise to sunset without intermission except a brief interval at midday for a meal consisting of bread soaked in unfiltered Nile water. This bread was sent to them by their relatives, and they had a meal of it before commencing work and another at night. They have also to provide their own baskets for carrying the excavated soil. They were engaged in filling these baskets with gravel (using their fingers for the purpose), climbing the sides of the cut, and tipping them on the outer slope. The majority had no implements but their hands. A limited number had short picks a foot long, which they also have to provide, the government contributing nothing whatever.

The day was excessively hot, and not a breath of wind. The temperature in my cabin with all windows open was 82 degrees in the shade. At the bottom of that trench it was much hotter. I should estimate it at 95 degrees. There was absolutely no shade. In this fiery heat and glare and amid dust they toiled all day long. They were clad in calico, mostly reduced to rags by the work they were engaged in. They wore on their heads felt skull caps exactly like those represented as worn by workmen in fourth dynasty bas reliefs. They were barefooted. Their calico rags formed their only covering at night, and they slept on the bare ground in the open air without any kind of shelter, although the nights are often very cold. Among them were many overseers armed with sticks, with which they often struck the men while carrying loads on their heads, without any apparent reason. Many had sore fingers and sore feet, for there were sharp flints among the débris.

I have seen negro slaves at work on the cotton plantations of Cuba; I have also seen the convicts at work at Portland. The conditions under which all these labored were greatly preferable to those to which these Egyptian fellaheen were exposed, and it must be remembered that most of them own farms and constitute, in fact, the yeomanry of Upper Egypt.

What struck me most as I gazed on the toiling multitude was the pitiable waste of human labor, for one-fourth the number, with proper tools and appliances and sufficient food, and with intelligent and experienced foremen to direct them, could have done the work far better and more quickly than the ill-directed efforts of that mob of men, without implements, weak from scanty diet and exhausted by hardship. An English navvy would laugh at their work as excavators, but the conditions as to food, temperature, and exposure under which they work would kill him long before the month was out. Ophthalmia is one evil that results. I can not imagine a better receipt for the wholesale manufacture of this malady than to work men to exhaustion in fiery heat and glare and dust all day and then to expose them at night to the heavy dew and frosty temperature, lying on the bare ground in their calico dresses.

It must not be supposed that because the government pays nothing for it that therefore forced labor, as now conducted, is cheap; on the contrary, it is most costly to the country. Every man there withdrawn from the cultivation of his farm represents a family by so much impoverished.

One-half of the able-bodied population is engaged for between three and four months in the year in forced labor. That means that the second crop on their farms is reduced in productiveness by one-half; that on the lands where 4 ardebs (21.76 bushels) per acre could have been yielded had all the hands remained at home, only 2 are yielded owing to deficient irrigation when half the hands are withdrawn; that is to say, that it amounts to a tax of 21s. ($5.04) per acre on every acre devoted to second crops. Where land is rented, not owned, these second crops often constitute all the return the cultivator gets, rent and land tax entirely swallowing up the first; the price the government pays is the pauperization of the people and the reduction of their taxpaying capacity, but that is not the whole price. There are not men enough in Egypt to cultivate it properly or to develop its resources fully; the government, grudging the cost of food and implements, is prodigal only in men, the very article that most needs here to be economized. If they can save the expense of tools by setting four or five men to do the work which one man with tools and food could easily accomplish, they send the five men and withhold the tools and food. I fear, also, that the sacrifice of men is not merely temporary; men can not be exposed with impunity to the hardships which I witnessed. The constitutions and health of many must be permanently impaired, even their lives shortened. Twenty thousand men are said to have perished in making the Mahmoudia Canal, and I can well believe it after what I witnessed near Keneh.

It must be accepted for a fact that forced labor exists with the consent of the great mass of the people of Egypt. I have heard them complain of this or that tax and suggest its abolition, and I have heard them complain of the unfair apportionment of forced labor in their district, but I never heard one single person of any class suggest the abolition of the forced-labor system. They admit it to be necessary, but it does not follow on that account that nothing can be done to reform its conditions. The first term of labor should be postponed till the first crops are thrashed out and sold and the second crops well established and less likely to suffer from defective irrigation. The men should be supplied by the government with nourishing food. Two or three intervals for food and rest should be allowed in the day, instead of only one. Proper implements for excavating should be supplied to them. Labor-saving machinery should be introduced where possible. Skilled foremen should direct the works. The men should be divided systematically into gangs, each gang with its own task marked out, instead of the desultory fashions which now prevail, for they work in a mob and every man is in his neighbor's way. Some shelter ought to be arranged for the night, if possible, or, at any rate, they should be supplied with a warm wrap, no matter how coarse; old sacks would be better than nothing.

REFORM OF THE CORVÉE SYSTEM.

When the English engineers began their work, in 1883, they found that all earthwork necessary in the construction and cleaning of canals was performed by this kind of labor. Under the original basin system, before the farmer had a title to the land he cultivated and while he was simply a slave, this practice might have been excusable. There are no good reasons, however, why it should have been continued after the reforms introduced by Mohammed Ali were put in operation. Under the old system the farmer had nothing to do when there was no water, and he could do nothing during the flood. Under the perennial system some kind of farm work is in progress throughout the year, and if the farmer is taken away from his land the results are as serious to the taxgatherer as to him. Perennial canals require a great deal more labor to keep them in repair than do the ancient inundation canals. This is because the canals are deeper and carry water throughout the year. The whole agricultural population was formerly employed a large part of the year in keeping these canals in condition, although but a small portion of the people so engaged were directly interested in them. So long had the system been in force in Egypt that immediate reform was impossible. The increased security to land titles did much toward bringing about a change for the better. The first khedival decree relating to the corvée appeared in January, 1881.

Articles 1 to 4 of this decree prescribe what works shall be maintained by the public.

Article 5 provides that all male inhabitants of the country, of sound health, between the ages of 15 and 50 years, with the exception of those indicated in the following section, are subject to corvée duty.

Article 6: The following persons are exempt from corvée duty: Law students of the Koran; those who recite the Koran; persons engaged in teaching; students of the mosques and schools; persons attached to charitable institutions, shrines, convents, and hospitals; those in the service of the mosques, tombs, and holy places having distinct offices; priests, monks, rabbis, and persons attached to the service of churches, temples, cemeteries of the various sects and holding permanent positions; people having professions or trades who pay professional taxes and who exercise their calling; also fishermen and boatmen; the watchmen of the villages.

Article 7: Every person who is subject to corvée duty can redeem himself by furnishing a substitute. The following persons can redeem themselves by a payment in cash: Inhabitants of isolated settlements who have been included in the census; Bedouins who own land or cultivate the same and who have heretofore been exempt from such labor; the inhabitants of the villages working on the state domain and the

Daira Sanieh in Lower Egypt, wherever these administrations have more than 100 acres, on the condition that the land is not rented and that the ransomed men shall devote their labor to cultivation. Forced labor is obligatory from the inhabitants of the villages where rice is the predominating crop, or where the land tax is adjusted as it is for such villages, but the corvée duty of such inhabitants will be only half of that required from the inhabitants of other villages.

Article 8: Where a cash payment is permitted in lieu of services, about $6 is required in Lower Egypt and about $4 in Upper Egypt. After the year 1882 the amount of this payment shall be fixed annually, and the minister of public works shall so notify the governors of the provinces one month before the commencement of work. The conditions which shall affect the amount of this payment are the quantity of material to be moved and the time when it is necessary to perform the work.

Article 9: The minister of public works can, when he deems it necessary, withdraw the privilege of the payment of cash instead of labor as provided for in article 7, or he can substitute machine work for hand labor.

Article 10: The money received in each province from this source will be entered in a special register and deposited in the treasury of the province and kept at the disposal of the minister of public works. These sums can be spent only on works which have for their object reduction or suppression of the corvée.

Article 11: It is the duty of the minister of the interior to collect and keep in service those subject to the corvée.

The khedival decree issued in 1882 permitted the Arab farmers to redeem themselves from the corvée by a cash payment, and the same decree frees the Bedouins from this service entirely. Under the provisions of this decree those having political influence gradually secured relief from both the payment and the corvée service and the whole burden fell on the poorer classes. Early in 1885 some of the fellaheen of one of the districts applied for an investigation to be made of the corvée conditions. It was found in an examination of the corvée service from 145,000 acres that the entire number of men furnished came from 33,000 acres. The state lands included within this district redeemed about half of the renters, and the large landholders, who own about 59,000 acres, paid nothing and furnished no labor.

The partial reconstruction of the barrage in 1885 brought about the first real relief to the fellaheen. This structure not only furnished water for the farmer during the period of low Nile, but also enabled the discharge to be regulated in such a way as to reduce the volumes of silt which were annually deposited. In addition to this relief $150,000 was spent in paying those who worked on certain canals. This was an experiment to see whether it was possible to relieve or wholly do away with forced labor. The work was entirely successful. Not only were the inhabitants better satisfied to carry it on, but the work was better done, and the money reverted to those who bore the burden of the tax. This kind of work is carried on by contract, and each person is paid for the volume of earth he removes. Owing to the improved quality of hand labor it was possible to clean canals in which 125,000 cubic yards of silt had deposited. At first it was estimated that machinery would have to be employed when the volume exceeded 50,000 cubic yards for any one canal. In 1886 the first systematic work of cleaning the canals was undertaken by the government, and this was gradually extended until all earthwork was carried on without the employment of the corvée. The cost of cleaning the canals amounts to nearly $2,000,000 per year. While this is a serious drain on the treasury of the country, yet it is a long step in advance of the conditions which existed prior to the initiation of reform. The corvée is still called out to watch the banks of the Nile during high water.

A number of decrees have been issued dealing with details regulating the corvée service, but they are comparatively unimportant. On December 19, 1889, the following decree was rendered:

> We, the khedive of Egypt, at the instance of our council of ministers and in view of the deliberations of the general assembly, decree:
>
> ARTICLE 1. The corvée is suppressed throughout Egypt.
>
> ARTICLE 2. The guardianship and charge over the dikes and other works, as well as all urgent measures in case of danger owing to the rise of the Nile, shall continue to be carried out at the expense of the inhabitants.
>
> ARTICLE 3. The corvée and redemption tax are replaced by the establishment, both on Ushuri and Kharadji lands, of a special tax with a maximum tax of $0.214 per acre, the total produce of which shall not exceed $741,500 per annum.
>
> The assessment of this tax shall be made by a further decree issued on proposal of our council of ministers, after consideration by the legislative council.
>
> ARTICLE 4. The produce of this special tax shall, with the authority of the commissioners of the debt, be employed under the conditions prescribed by our decree of the 14th of June, 1889, for the sum of $1,235,750 provided for in the said decree.
>
> ARTICLE 5. Our ministers of finance and public works are charged, in so far as they are each concerned, with the execution of the present decree.
>
> Done at the palace of Abdin the 19th of December, 1889.
>
> (Signed) MÉHÉMET TEWFIK.
>
> By the Khedive:
>
> The President of the Council of Ministers.
>
> The Minister of Finance.
>
> (Signed) RIAZ.
>
> The Minister of Public Works.
>
> (Signed) MOHAMED ZÉKI.

Many preliminary steps were necessary before this final decree could be rendered. Some of the foreign powers objected to increasing taxation for the purpose of relieving the fellaheen in this work. The French were particularly active in this opposition.

Although to-day the fellah is not imposed upon as he was twenty years ago, yet he does not enjoy liberty as we understand it. The work of watching the Nile levees during high water results in considerable hardship to the farmer. The following table shows the number of men called out during the twenty years from 1880 to 1899, inclusive:

Number of men called on for corvée duty, 1880–1899.

Year.	Number of men.	Year.	Number of men.	Year.	Number of men.	Year.	Number of men.
1880	110,385	1885	125,936	1890	48,488	1895	36,782
1881	281,283	1886	95,093	1891	44,962	1896	25,791
1882	262,923	1887	87,120	1892	84,391	1897	11,069
1883	202,650	1888	58,788	1893	32,752	1898	34,770
1884	165,105	1889	49,904	1894	49,488	1899	17,564

The number of men needed in this work depends upon the stage of the Nile during flood. The higher the flood the more men are required to watch the banks during this critical period. The difference between this work and the cleaning of canals is that those employed in the latter service receive compensation fixed by the government. Service is compulsory in both cases. If an accident occurs to the government railway line, men are forced to leave their homes and put it in repair, and are paid for their services as the government may deem sufficient. It can not be said, therefore, that forced labor has been abolished. Those who are best acquainted with the conditions admit that the system has simply been modified and reformed.

CONCLUSIONS.

The climate of Egypt being mild, the needs of the people are easily satisfied; the population is dense and the individual holdings of land are small. Labor is cheap, enabling much to be accomplished by the use of crude implements which could be performed profitably in America only by the employment of modern machinery. The irrigation canals of Egypt convey water to the farms, but the irrigator must raise the water for his fields. He has few other duties which demand his time and energy during the growing season, and therefore can use with profit machinery which requires a large expenditure of labor but little expenditure of money. In lifting water from the Nile the Egyptian deals with the same obstacles as the irrigator in many localities in the West where water can be secured at depths ranging from 10 to 25 feet, but there the resemblance ceases. The standard of living of the American irrigator is higher, his farm is larger, and the returns from an acre are less. He can not adopt water-raising devices of low efficiency like the shaduf or natali. The hoe, practically the only tool used in distributing water over the fields in Egypt, has no merit to the American farmer. We can not, therefore, learn much from the Egyptian irrigator.

Many of the irrigation structures of Egypt are models of their kind. The barrage below Cairo is one of the most interesting dams in the world. Its architecture reflects some of the recent political struggles in Egypt. The towers which embellish the dam should be classed with the ruins bequeathed to the modern world by ancient Egypt. The barrage is a monument to the French engineers, while the fortifications along it remind us that it was only a few years ago that the caprice of the khedive overshadowed the designs of the engineer. The Assiut dam follows the general plan of the barrage below Cairo. The design of the dam at Assuan is new in Egypt as well as in the world. It marks the beginning of a great reservoir system which will ultimately control the waters of the Nile and furnish a supply to every arable district of Egypt. The head gates, waste gates, regulators, and bridges of the larger canals will always be objects of study for irrigation engineers of other countries.

The excellence of the recent irrigation works of Egypt is beyond question. The fame of the dam at Assuan has been heralded throughout the civilized world; but such works are costly. Before the distributary systems are perfected the cost of the system supplied by the Assuan reservoir will exceed $57 per acre of land irrigated. Such an outlay is not at present profitable in the United States. It is advisable, nevertheless, for us to study the larger irrigation works of Egypt, because it may be possible for American engineers to modify these designs to suit the needs of irrigation here. Many of the smaller details of construction can be readily introduced

The Nile is an easy stream to divide, hence laws for the economical distribution of water are not so severely tested as they will be on the streams of the arid West. Water is diverted only at the lower end of the Nile, and not from all its ramifying tributaries, as is the case on the Missouri and Colorado. In addition, Egypt is one of the few countries where the water supply can be made adequate for the needs of all by storage. This will not be possible in the United States except under rare conditions, where the area of irrigable land along a river affording the supply is comparatively limited. In Egypt the demand for land will in a few years exceed the demand for water. With us the area of irrigable land will ultimately be limited by the water supply.

The Egyptian irrigation law aims to bring about such a distribution of the water of the Nile that the country as a whole will produce the largest returns and the treasury receipts be the greatest. The irrigation laws of the Western States of the United States are framed to protect the individual farmer, and not for the purpose of producing revenue. This fundamental difference in the objects to be attained makes Egypt's administrative system inapplicable to this country. There does not seem to be any reason for changing our policy. On the contrary, it seems wise that our irrigation administration should promote the prosperity of the water user as far as practicable, so that we may say in the words of Ameni, as inscribed on his tomb at Beni Hassan, 50 miles above Cairo. "And behold, when the inundation was great, and the owners of the land became rich thereby, I laid no additional tax upon the fields."

APPENDICES.

Appendix I.

Note.—The laws as given in these appendices are free translations of the texts, as given in La Législation en Matière Immobilière en Egypte, Le Caire, Imprimerie, Nationale, 1901.

POWERS OF THE GOVERNORS AND INSPECTORS OF IRRIGATION.

[Regulation of December, 1885, fixing the relation between the governors and inspectors of irrigation.]

(1) It is the duty of the governor to see that a just distribution of the water is made in the various districts composing his province. He will make known at an opportune time to the irrigation inspectors appointed by the minister of public works the places where more water is needed and at what times, and hear the complaints on such subjects as may be addressed to him by the chiefs of the villages.

(2) It is the duty of the inspectors to satisfy all demands as far as possible, and where they can not for any reason carry out these instructions they shall report the matter to the governor and communicate with the minister of public works. The governor on his part shall inform the minister of the interior, and the two ministers shall together take the matter under consideration and, if necessary, report it to the council.

At the beginning of each year the governor, with the agricultural council, which is assisted by the engineers, shall specify in the ordinary manner the various works which are to be executed and shall determine the number of the corvee necessary for cleaning canals and for construction.

In order that the governor may be able to undertake this work with full knowledge of the facts, the chief engineer shall report to him his estimates and calculations some days before the meeting of the agricultural council.

The governor shall put himself in direct communication with the chief engineer on all questions which may arise during the course of the year. If he does not obtain satisfaction he may appeal to the inspector, and, if necessary, to the minister of the interior.

(3) The technical control of the distribution of water, the partial or complete closing of gates, belong wholly to the inspectors, and nothing may be done without their written orders. Consequently, if the governor believes that it would be better to partially open or close any gate he must address the chief engineer, and, if necessary, the inspector, giving his reasons and all possible evidence. The engineer and inspector may be able to approve and act accordingly. If not, they must explain to the governor what facts and evidence the minister of the interior and the minister of public works should have in case the question is appealed to them.

(4) During high water in the Nile, or whenever necessary to avoid disaster, and when the governor does not have near him an engineer whom he may consult, it is the duty of the governor to do whatever in his judgment may be necessary, whether to throw stones in the water or to use any other means for adding to the security of

irrigation works. In such cases the governor should telegraph to the inspector immediately, requesting the aid of the chief engineer.

If the engineer of the province be present, he, and not the governor, directs what measures to adopt, and he is held responsible for the same.

If, however, the governor gives orders contrary to those of the local engineer, the latter must obey, but at the same time give notice that discord exists, after which the governor is responsible for what takes place.

The inspector shall arrange matters so that the governor may be accompanied as often as possible in his journeys along the levees and canals during high water by the chief engineer or some one delegated by him.

(5) The engineers are under the minister of public works, but they owe to the governor the respect due to the principal representative of the government in the province. They should respond to his demands and give him all the information he may desire. When the governor has reason to believe that the local engineer acts without or beyond the orders of the inspector in that which concerns the making of regulations relative to the use of water, which regulations must always be communicated to the governor and published, he must study with care the conduct of the engineer, make full inquiries regarding his acts as well as the acts of those under his orders, and shall make known to the inspector the results of these inquiries.

(6) No new work may be undertaken without the previous sanction of the council of ministers. Concerning important improvements which the inspector believes should be made in the irrigation or drainage of a region, he must act in concert with the governor, and in all cases they must inform the minister of the interior and the minister of public works, who shall be members of the council of ministers.

In public improvements and reforms of less importance it is the duty of the inspectors to personally inform the governor regarding what they propose to do, the effects of the proposed changes, and the obstacles which they will have to overcome. Notification in writing, either English or Arabic, is not sufficient for this, and the inspectors must never fail to explain their ideas at least by maps and diagrams. Because of his special knowledge of the agricultural interests the governor can and should indicate how the proposed work might occasion loss or damage to private or public property. The two ministers and the council must be informed also.

(7) The number of the corvée, as before stated, is determined by the agricultural council. The governor must decide as to the number of men who should be included in the corvée, and agree with the engineer as to the order in which the canals should be cleaned and the time for said work.

The governor is not to be called upon for the technical execution of the work; the chief engineer is alone answerable and bears all responsibility for the completed work.

The governor may, should there be occasion therefor, call upon the chief engineer to permit those of the corvée who have finished their work to return home.

(8) When, for any reason, the inspector desires to close a canal for more than fourteen days, he must inform the governor of his intention as soon as possible, so that the latter may present his objections if he has any.

(9) *Irrigation works.*—Irrigation works may be divided into two classes. The first class includes those for which bids are advertised in the official journal, which bids are submitted under the prevailing rules of the minister of public works. These works comprise all excavation requiring more than a thousand men per day, all masonry work costing more than £200 ($974), and all work in which machinery is necessary.

In work of this class the governor will not be consulted as to the choice of the contractor, but he shall be informed regarding the nature of the contract. During the execution of the work he must, if he deems necessary, call the attention of the engineer to the manner in which the contractor is executing the work.

(10) The second class covers the excavation and cleaning of small canals, small works where masonry is not needed, and repair of masonry works. Contractors shall submit bids to the governor for work of this class. The inspector shall submit to the governor a copy of the specifications. The bids shall be opened and a contractor chosen to the satisfaction of both the governor and the inspector or his assistant. It is not necessary to accept the lowest bid. In work of this class the governor must always judge as to the reliability of the bidders. The governor should, if possible, favor local contractors.

CANALS AND LEVEES.

[Decree of February 22, 1894, concerning regulations regarding canals and levees.]

PUBLIC CANALS AND LEVEES.

ARTICLE 1. The word "canal" refers to a water course which serves for the entire or partial irrigation of the lands of more than two villages. All canals of this kind are considered public property. They are generally constructed and maintained at government expense and are a part of the public domain.

The use and occupation of banks of canals are permitted only under certain restrictions laid down in article 21 of this decree.

PRIVATE DITCHES.

ARTICLE 2. By the word "rigole" is understood a water course which serves for the irrigation of the land of one or two villages or of land belonging to one person or to a single family living in one community even if belonging to several villages.

All rigoles are considered private property. The cost of construction and maintenance is borne by those who derive profit from the works.

In case of delay in cleaning these works the government may perform the work at the expense of the proprietors. The sum thus spent will be distributed by the governor in proportion to the taxes paid by each, and it will be collected in conformity with the provisions of the decree of March 25, 1880.

However, if a ditch serves for the irrigation of 1,000 acres belonging to one or several persons it can always, upon request of the owners, be considered a public waterway.

DRAINS.

ARTICLE 3. The word "drain" indicates a channel in the earth for carrying away rain water, drainage water, or water from irrigated fields.

A drain is public when it serves more than two villages; private when it serves one or two only, unless it drains a surface of more than 2,000 acres in area, when it is considered a public work, although it may be situated in one village.

The public drains are maintained by the government and the private drains by the parties interested. The provisions of the second paragraph of the preceding article are applicable to private drains.

WORKS FOR PROTECTION AGAINST INUNDATION.

ARTICLE 4. "Works for protection against inundation" are levees, transverse and longitudinal dikes, and all structures serving to protect farms and villages from the overflow of water.

These works are considered public property and are wholly under government control.

Private levees upon the banks of the Nile, or those which form the boundaries of the basins and which are constructed by the owners, must be maintained at the expense of those benefited.

POWERS OF IRRIGATION INSPECTORS AND CHIEF ENGINEERS.

ARTICLE 5. Irrigation inspectors are the representatives of the minister of public works and have under them the chief engineer and all those in the irrigation administrative service. Their powers and their relations to the governor are fixed by the regulations of December 31, 1885.

PUBLIC WORKS ON PRIVATE LAND.

ARTICLE 6. The owner of land crossed by a public ditch, drain, or other work destined to serve the lands of neighbors can not, without the written consent of the owners of the lands served, till the land occupied by such works in such a way as to destroy the usefulness of the works.

STOPPING OF WATER-RAISING MACHINES AND CLOSING OF CANALS.

ARTICLE 7. No indemnity can be claimed from the government for loss occasioned by a reduction or stoppage of the flow of water in a canal resulting from extreme necessity or having for its object repairs or changes recognized to be necessary, or by any measure which the irrigation inspector may deem necessary in order to maintain the volume or regulate the flow of water—such, as for example, the closing of a canal or the suspension of irrigation for a certain number of days on all or a part of a canal, so that other places in greater need of water may receive it.

In case it may be necessary to clean or repair a canal the irrigation inspector, through his agent, the chief engineer of the province, shall determine when water may best be dispensed with for irrigation that these operations may be carried on. However, having commenced any work of this kind, the irrigation inspector should act in accord with the governor, as required by the provisions of the regulations of December 31, 1885, fixing the powers and relations of inspectors of irrigation and governors of provinces.

The governor should notify and consult those interested or their legal representatives.

CONSTRUCTION OF PRIVATE DITCHES.

ARTICLE 8. If the citizens of a village desire to construct a canal on their own lands for their own use they shall apply to the governor. He will communicate the application to the inspector of irrigation, accompanying it by his recommendations and advice, and if the inspector agrees, the governor will approve or reject the application as the circumstances may warrant.

The ditch thus authorized shall be constructed at the expense of the applicants and their associates.

However, privileges so extended shall not permit the parties to debar neighboring property owners from utilizing the ditch for the irrigation of their lands, even during low water, after the original applicants shall have received what they need for their own lands. These neighbors shall in such cases become contributors toward the cost of construction and maintenance in proportion to the extent to which their lands may be benefited by the ditch.

DITCHES THROUGH LANDS OF PERSONS NOT BENEFITED.

ARTICLE 9. When a property owner finds that, without the construction of a ditch upon land not belonging to him or not served by a Nili[a] canal or by a ditch already constructed on the property of others, it is impossible for him to irrigate his own land, on account of his being unable to arrive at an amicable agreement with the proprietors of the private works or their legal representatives, he may make a statement of the case to the governor, who will communicate the same to the inspector of irrigation, with his recommendations and advice. The latter will then examine the situation, on the ground, and will give his decision after hearing the parties interested or their legal representatives, should such appear. The chief engineer of the province or his deputy may be delegated for this work.

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[a] A canal which flows only during the Nile flood.

Fourteen days' notice shall be given as to the day and hour of the inspection. Such notice shall be given either to the owners or to their legal representatives, as the case may be.

But if the ditch or Nili canal is to furnish water either running naturally or elevated by a machine, and the property owners oppose its construction because it may injure the land it traverses, the inspector of irrigation shall go to the place himself and base his report on a careful survey.

If the report is favorable to the applicant, and the governor, after having acquainted himself with the facts, agrees with the inspector, a decision to this effect shall be rendered by the inspector. This decision shall be transmitted, as prescribed by law, to the opposing parties. The latter may, within fifteen days from such notice, appeal to the minister of public works, whose decision shall be final.

If the governor and inspector of irrigation do not agree, the case shall be submitted to the minister of public works. The applicant must always pay for the land occupied by the new ditch and the delinquent taxes on the same; also indemnity for all damage occasioned. The amount to be paid shall be fixed by the commission mentioned in article 27 of this decree.

Article 10 of the decree of March 8, 1881, is hereby repealed.

INSUFFICIENT SUPPLY OF WATER IN A DITCH.

ARTICLE 10. An irrigator who believes that he does not have sufficient water for his purposes, should notify the governor, who should in turn communicate with the inspector of irrigation, accompanying his report by his recommendation and such information as he may deem necessary, so that the inspector may determine whether or not the ditch which irrigates the cultivated land has sufficient capacity, and as to whether it should be enlarged. The inspector will base his judgment on the extent of irrigated land and the character of the irrigated crops.

If the neighboring property holders object to the enlargement of the ditch, as may be recommended by the inspector, the provisions of the preceding article are to be observed, and if the enlargement is for the passage of summer irrigation water the regulation set forth in paragraphs 2, 3, and 4 of article 9 shall apply.

EXCHANGE OF DITCHES.

ARTICLE 11. The rules and forms prescribed by article 9 will apply also where a party desires to irrigate his land during high Nile by means of a ditch other than the one which ordinarily serves him, but during low water no exchange of ditches will be permitted without the consent of the parties owning the land through which the new ditch would pass.

CONSTRUCTION OF LATERALS, OR INSTALLATION OF WATER-RAISING DEVICES ON CANALS.

ARTICLE 12. If a party desires to build a lateral gate, or a sakiyeh, or other elevating machine on a canal to irrigate the land bordering the same, he must submit his request to the governor, who will communicate it, accompanied by his recommendations and advice, to the inspector of irrigation; the latter will refer the matter to the chief engineer of the province, who, in the case of the sakiyeh, if he approves the request, will furnish the necessary authorization, but if it concerns a lateral will return the papers to the inspector for his approval.

In all cases a copy of the authorization shall be transmitted to the governor, together with a statement that the discharge of the canal is sufficient to supply the lateral or the land to be watered by the sakiyeh without injury to those using water from the same canal below.

The chief engineer shall first require the applicant to agree to pay all expenses incident to and judged necessary for the regulation of the flow of water into the lateral and the maintenance of the banks of the canal in good condition. He shall designate the location of the lateral or sakiyeh.

Regulations for establishing fixed or portable elevating machines operated by steam, wind, or water power are set forth in the decree of March 8, 1881.

It will not be allowable in any case to install a sakiyeh or a tabout without first securing a permit. This permit will be furnished free of charge.

CLOSING A DITCH TO PREVENT INJURY TO ADJACENT LANDS.

Article 13. When, upon the claim of the owners interested or their legal representatives, the inspector of irrigation finds that a ditch is useless for irrigation, an obstacle to the drainage of bordering lands, that it absorbs water from bordering lands or loses it in transit, or, in fact, that it is a detriment to agriculture in any way, he should, after consulting the governor and after the latter has heard the interested parties, communicate his recommendations to the minister of public works, who will order the canal to be closed at the end of the harvest and will permit the adjoining property holders to fill it up if it be shown that the land irrigated by the ditch can be watered from another without injuring lands or agriculture in any way. The tract of land occupied by the ditch thus filled in shall be subject to the laws relating to such land.

INCREASING OR DIMINISHING THE SIZE OF THE HEAD GATE OF A DITCH OR CHANGING THE LEVEL OF THE BOTTOM OF THE SAME.

Article 14. If the inspector of irrigation believes that a head gate of a ditch is too large or that its flow permits the passage of a volume of water in excess of that needed by the land irrigated by the ditch, he should so inform the governor, who will invite the parties interested, or their legal representatives, to meet him on a certain day. After having the opinion of the inspector stated to them, they will fix, if they approve the recommendations of the inspector, the time when changes may be made. The time should be so chosen that crops will not need irrigation while the work is being performed.

If the parties object to the recommendations of the inspector, the case will be referred by the governor to the minister of public works, who will act as he deems expedient regarding the proposed changes.

If it is necessary to enlarge the head gate of a ditch or to lower the level of the bottom of the same so that sufficient water may be delivered, a certain time shall, in like manner, be fixed for the alterations.

In all work of this nature the government will bear the expense.

DRAINS PASSING THROUGH LANDS OF PARTIES NOT BENEFITED.

Article 15. Where, in order to drain his farm, a party has to construct a channel across the land of another, and the parties can not come to an amicable agreement, a complaint should be presented to the governor, who will transmit it, accompanied with his recommendations and advice, to the inspector of irrigation. The latter will fix the course of the drain; the governor and the inspector of irrigation shall agree as to how the land for the drainage channel shall be acquired. If they fail to agree, the case shall be submitted to the minister of public works, who, if he approves of the construction of the drain, shall take such steps as he may deem necessary to accomplish the work. All expenses thus incurred and the indemnity charged must be paid by the parties benefited. The construction of the drain shall not in any way injure land through which it passes.

REPAIRING A DITCH OR DRAIN TO PREVENT DAMAGE.

Article 16. A party whose land is injured by a ditch or drain which passes through it, whether such injury be due to a partial filling in of the ditch or drain or to insecure construction of the banks of the same, may appeal to the governor, who, after consulting with the inspector of irrigation or with the chief engineer of the province, may order the closing of the ditch or drain or may compel the owners to clean it if he deems this sufficient. If the ditch or drain is essential for serving other lands, the governor will require the owner or owners of the same to keep it in good condition or pay damages to those injured.

CHANGING THE LOCATION OF A DITCH WHICH DOES NOT MEET THE DEMANDS OF THE IRRIGATORS UNDER IT.

Article 17. When a party finds that a ditch passing through his land makes the irrigation thereof difficult, and he desires to replace the channel by another, he may present a petition to the governor, who will transmit it, accompanied by his recommendations and advice, to the inspector of irrigation, who, after having consulted with the governor, will authorize the closing of the ditch and the substitution of another at the expense of the owner of the land, provided that the new ditch is in all respects as good as the first and fulfills the required conditions, and that the original channel be not closed until the new one is in condition to be used.

But if the ditch concerns only the owner of the land through which it passes, he may replace the same by another channel upon his own land without having to obtain a permit.

DIFFICULTIES WHICH MAY ARISE IN CONNECTION WITH THE REPAIR OF DITCHES.

Article 18. If any party disagrees with his associates as to whether or not a canal should be repaired, and so notifies the governor, the latter shall delegate the chief engineer to make investigation on the ground and ascertain the facts. If it is considered necessary to have the repairs made, the governor will notify the interested parties to do so.

But if the parties are found to be unable to perform the necessary work, either for want of labor or money, the government may defray the expenses necessary for making the repairs and reimburse itself for the money so expended by numerous payments from those benefited, the amounts of such payments to be fixed by the province according to the means of the parties. The government may renounce all claims for reimbursement if the parties are recognized as being poor.

The minister of the interior will decide as to whether poverty exists or not

DESTRUCTION OF DIKES OR FILLING IN OF DITCHES OR DRAINS.

Article 19. If any party complains to the governor that one of his associates in an irrigation ditch or drain maintained at the expense of those interested, under the provisions of article 2, has destroyed the banks or has filled in or encroached upon a part thereof, the governor will communicate the grievance, accompanied with his recommendations and advice, to the inspector of irrigation, who will make a personal examination of the ground or delegate the chief engineer of the province to do so, after having given notice to those interested at least fourteen days in advance. If it is found that dikes have been destroyed or channels filled in, the inspector will make an estimate of the cost of reestablishing the works as they formerly stood, and the governor will require, according to law, the offender to restore the property he has damaged. In case he refuses he will be obliged to bear the expense of such repairs.

In case an owner or a tenant complains to the governor that some one has intercepted the water of a ditch which serves him for irrigation, the governor, as stated in the foregoing paragraph, will transmit the complaint, accompanied with his recommendations and advice, to the inspector of irrigation, who will visit the place himself or delegate the chief engineer of the province to do so, after having given notice to the interested parties at least fourteen days in advance; if it is found that the complainant actually irrigated his land from the same ditch during the preceding year, the inspector of irrigation will so inform the governor, who will take such lawful measures as may be necessary in order that the water may flow as formerly, and that nothing may prevent his use or enjoyment of the ditch. The governor will proceed immediately in the execution of these measures, all expenses being borne by the party or parties who intercepted the water. These expenses may be, in all of the above cases, recovered in the manner prescribed in the decree of March 25, 1880.

REMOVAL OF TREES PLANTED ON LEVEES AND CANAL BANKS.

ARTICLE 20. If it is found that trees planted on levees, or banks, or footpaths of canals are private property, and are obstacles to the flow of the water, to navigation, or to travel on the banks, the inspector of irrigation or the chief engineer of the province shall order the owner to remove them. If he does not do this within eight days, the inspector, after having obtained the written consent of the governor, shall break or cut down the trees, sell the wood, and remit to the owner the receipts from the sale after deducting expenses.

CULTIVATION OF THE BANKS OR BED OF A CANAL.

ARTICLE 21. The customary practice of cultivating the sides of canals not reached by the water and the beds of Nili canals will be permitted, but the cultivator of such land can not claim any damage for injury occasioned by necessary repair or cleaning of canals. However, the inspectors will enjoin the agents in charge of the work to take all possible precautions to prevent loss to the growing crops.

A farmer of such government land will not be required to pay rent therefor when the crop shall have been damaged as a result of necessary public work executed before harvest time. He will, however, be obliged to bear the loss of the damaged crops.

MAKING A ROAD ALONG A CULTIVATED BANK.

ARTICLE 22. If it is necessary to use for a public highway the bank of a canal ordinarily cultivated, or if for any reason it is desired to stop cultivation thereon, the inspector of irrigation will request the governor to inform the farmer that cultivation will not be permitted after the crops then growing shall have been harvested. If, in spite of this notification, the farmer persists in using the bank for raising crops he will have no claim against the government should the crops be destroyed by order of the governor. But if the land along the bank yields revenue through taxation, the government must remit the taxes thereon and declare it a public highway.

CONSTRUCTION OR REPAIR OF PRIVATE HEAD GATES ALONG THE BANKS OF THE NILE OR OF A CANAL.

ARTICLE 23. If the inspector of irrigation finds a head gate on the bank of the Nile or of a canal, or any other works of protection, badly constructed or in poor condition, or in any way a source of danger to the banks, he will inform the governor, who will give orders to the owners of the works to make changes or repairs within a period of forty days during the winter season. If the owner fails to do this the inspector will request the governor to set aside another forty days for the accomplishment of the work.

If, after the second notice on the part of the governor, the owner of the head gate refuses to make the changes or repairs, the governor may have the work done and the expense will be recovered as provided in the decree of March 25, 1880.

If the construction of the head gate is not finished at the time of high Nile, the inspector of irrigation may order its immediate closing and ultimate removal where the security of the banks demand it. He should be careful to inform the governor of his action, and to conduct the water in some other way than through this head gate to the lands usually irrigated.

WORKS FOR PROTECTION AGAINST INUNDATION.

Article 24. When, to protect the country from inundation, it is necessary to occupy a tract of land belonging to individuals, whether it be cultivated or not, or to destroy a building of any kind situated on the said land, the area of the property so occupied will be measured, and the valuation will be fixed by the commission provided for in article 27. After having heard the owner and the inspector of irrigation the commission will inform the governor of the estimated advantages resulting from these works.

The sum fixed by the commission will be paid by the minister of public works. No appeal can be taken from the decision of the commission.

In case of danger during high Nile the governor may act immediately. He may occupy land, whether cultivated or not, destroy a house or any other structure in the building of works necessary for protection; in this case the estimate of damages will be made by the governor or his deputy, acting with the chief engineer or the engineer of the district and four prominent persons, two of whom shall be chosen by the owners of the property and two by the governor. In case of a tie the governor or his deputy shall cast the deciding vote.

The damages shall be paid by the minister of public works.

CHANGE IN THE COURSE OF THE NILE.

Article 25. If the Nile should form, owing to a change in its channel, an island or a deposit of alluvial soil near a bank upon which is erected an elevating machine duly authorized by the government, and the government should deem it expedient to sell or rent this island or the tract of land, the owner of the machine shall have a right to dig a ditch through the alluvial land to bring water to his machine without indemnification to the tenant or owner.

LOADING AND UNLOADING BOATS.

Article 26. Boats will be allowed to load and unload their cargoes at all times at the landings established for that purpose upon the banks of the Nile or of canals, provided that no damage be done to these banks and that travel along the same be not impeded.

When the landing places are separated from the water by land belonging to private individuals and can not be reached by any other route, the owners of the boats and of the land must agree upon the location of a road for the transportation of the cargoes of the boats, as well as upon a reasonable price for the right of way. If the owner of the land objects to the road, he will be obliged to accept the price for the right of way fixed by the commission provided for in article 27.

Generally, the owners of boats will be permitted to construct or repair them only on the footpaths near the water edge.

BOARD OF APPRAISERS.

Article 27. A commission is hereby instituted to act where parties fail to agree on the amount of indemnity due, whether it be for lands necessary for the construction of ditches or drains or for any other case of indemnity provided for in this decree.

This commission shall be composed of the governor or his deputy, as president, the chief engineer, and two prominent citizens of the province chosen by each of the interested parties.

In case of a tie the president shall cast the deciding vote.

If the chief engineer is absent or hindered from attending, the inspector of irrigation shall appoint the principal deputy engineer to take his place.

OWNERS OF BOATS CAN NOT COLLECT DAMAGES FROM THE GOVERNMENT.

ARTICLE 28. The owners of boats or of cargoes can not claim any indemnity against the government for delay occasioned by the closing of a canal or by insufficient water in the canal or in the Nile. They shall be advised of the closing as soon as possible.

WRECKING OR GROUNDING OF BOATS.

ARTICLE 29. If a boat is wrecked or runs ashore along the Nile or in one of the public canals or in a basin in such a way as to form an obstacle to navigation or to the free passage of the water, the governor will notify the owner of the boat, who is held responsible for notifying the owner of the cargo to remove the boat, and if the latter does not do so within eight days after receipt of the notice the governor will have the work done at the expense of the owner, and the latter will have no claim against the government for indemnity for any damage which may be done to the boat or cargo in the course of such removal.

If the owner does not pay the expense of removing the boat within eight days after notification to do so, the governor shall have the right to sell the boat and its cargo. The returns from such sale shall be remitted to the owner after deducting the said expenses. If the expense of removal is in excess of the value of the boat and cargo combined and the owner is unable to pay the difference on account of poverty, such excess shall be borne by the government.

Should a boat founder in a narrow canal or in a lock or in front of the opening of a lock or head gate, etc., so as to stop navigation or render it difficult or diminish the discharge of water in the canal or through a lock or head gate, the inspector shall take immediate measures for removing the said boat from the passage so rendered dangerous, and at the same time inform the governor regarding the whole matter.

The expense of removing the boat will be borne by the government, but the owner will have no claim against the government for any damage which may be done to the boat, its accessories, or cargo in this work.

As to the procedure after the boat has been removed from a channel where it threatened danger to navigation or other interests, the provisions of the first part of this article shall apply.

ESTABLISHMENT OF FERRIES ON A CANAL.

ARTICLE 30. In order to establish a ferry on a canal it is necessary that the proposed plan and site be approved by the inspector of irrigation, in addition to the permit from the minister of finance.

In regard to ferries already in operation, if the inspector of irrigation believes that they are so located as to be injurious to irrigation or navigation and that they can be moved to a neighboring site without interfering with traffic, he may notify the governor to have the change made.

If such change be not possible, the inspector of irrigation and the governor will, after conferring, apply to the ministers of finance and public works, who will decide whether the ferries should be suppressed or not. If they decide that such action should be taken the ferries shall be relieved from taxes and replaced by bridges which shall be public highways. The owners of the ferries will have no claim for indemnity against the government.

Article 31. It is prohibited, under the penalties prescribed by the native penal code, for anyone to require or collect any payment whatsoever for the privileges which authorized boats have of loading and unloading their cargoes on the banks of the Nile, of a canal, or of a public drain.

OFFENSES.

Article 32. Offenses will be punished by imprisonment from fifteen days to two months and a fine at least equal in amount to the damages caused, to be judged by the minister of public works, but the fine can not in any case exceed twice this amount.

First. Those who, without special authorization—

A. May have obstructed a water course by a dike, rocks, or any other obstacle.

B. May have opened or closed the gates of locks or interfered with any of the machinery which serves to protect the bridges or head gates.

C. May have broken a dike that was constructed across a canal, with the object of closing or reducing the discharge.

D. May have established on the banks of the Nile, of a canal, or of a public drain any structure whatever, hydraulic wheel, sakiyeh, pump, etc. (all structures or machines established under these conditions will be immediately removed).

Shadufs, natalis, and Archimedean screws may be established without securing permits, provided that the banks are not cut or in any way damaged.

E. May have cut the banks of the Nile or of an irrigation canal or drain, or constructed a gate for the passage of water.

F. May have removed the earth forming the banks.

G. May have changed in any way a lock or a gate constructed of masonry, whether the lock or gate be public or private property, constructed upon a bank of the Nile or of a public canal.

H. May have removed earth, stone, wood, or any other material from the banks of the Nile or of a canal or from any work of protection, or who may have committed acts which might injure works of art.

The sheiks of the villages who may have taken charge of these works of art will be held legally responsible by the government for the said acts, unless they have informed the government that they will no longer act in this capacity, so that guardians might be appointed by the government.

Second. Those who may have interred a body in the banks.

Third. Those who may have taken water from a canal, whether by opening the gate of a canal or ditch or by making an opening in the bank or by raising the level of the water during the time the inspector of irrigation or other duly appointed authority shall have given notice that water should not be used.

Article 33. The following offenders will be punished by a fine of from 25 to 200 P. T. ($1.23 to $9.86) and imprisonment from five to thirty days:

First. Those who, without written authority from the inspector of irrigation, may have diverted water from a drainage canal to a public canal.

Second. Those who, without special authorization, may have constructed over a canal any bridge, either permanent or temporary, or who may have established a pipe or a siphon.

Article 34. The following offenders will be punished by a fine of from 10 to 50 P. T. ($0.49 to $2.47) and imprisonment from one to fifteen days:

First. Those who may have deposited upon the banks or berms of a canal the material obtained from excavating or cleaning a ditch, a conduit to a sakiyeh, or a steam pump.

Second. Those who may have damaged the banks of canals or public drains by running water over them from the fields or by discharging into the channel of a public drain sand or mud carried by water.

Third. Those who may have driven stakes in a canal to hold fishing nets.

ARTICLE 35. Those who may have thrown into the Nile, a canal, or a public drain dead animals or any other substance which would taint the water will be subject to a fine of 200 P. T. ($9.86).

Those in charge of the guards must always remove dead bodies from the water and bury them.

ARTICLE 36. The penalties, fines, and imprisonments provided for in articles 32, 33, and 34 may be applied separately.

ARTICLE 37. In addition to the prosecution for offenses as above provided for, offenders will always be required to restore premises to their former condition; if they refuse, the necessary work will be performed at their expense by the government, and the sum expended will be recovered in the manner prescribed in the decree of March 25, 1880.

ARTICLE 38. Offenders will be tried before a commission composed of the governor, the chief engineer or his deputy, and three prominent citizens of the province, to be chosen by the minister of the interior.

A majority vote shall decide.

No appeal may be taken if the sentence carries a fine only.

Where the offender is condemned to imprisonment, he may appeal to a special committee sitting at the ministry of the interior and composed of the under secretary of state as president, a khedival councilor, and a delegate from the ministry of public works.

The appeal must be lodged by a declaration to the province or to the government within three days after the decision has been handed down.

The appeal will not be received unless the party condemned has at that time paid the fine and damages imposed, subject to refund in case of acquittal.

ARTICLE 39. Special regulations of the minister of the interior shall fix the procedure to be followed, whether before the commission or before the special committee.

ARTICLE 40. The sheiks and watchmen of the towns and villages, the overseers of the chifliks and ezbehs,[a] of the government lands, and of the Daira Sanieh will be held responsible for the safe-keeping of the dikes and canals and all works of art which may be located within their respective jurisdictions and which have been consigned to their care. In case of offense they will be held personally liable for the expense of repairing the works should the offenders be not apprehended.

ARTICLE 41. The fines and other expenses shall be collected under the provisions of the decree of March 25, 1880. In case the fine is not paid, the condemned shall, in lieu thereof, be imprisoned one day for each 30 P. T ($1.48) of the fine. Such imprisonment will be ordered by the governor.

ARTICLE 42. All previous acts in conflict with this decree are hereby repealed.

ORDER OF THE MINISTER OF THE INTERIOR OF JULY 16, 1898.

ARTICLE 1. All infractions of the law of February 22, 1894, relative to levees and canals, shall be proven by testimony drawn up and signed by the engineer of the district or by a referee appointed by the chief engineer, and signed in addition by the omdeh[b] or by one of the sheiks of the village in the province where the offense was committed.

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[a] Chifliks are concessions of large areas of land related to the Abadieh lands and ruled by the same decree of 1842. They were given to the vice-royal family exclusively. Under Abba Pasha, however, the government ceded some of this land to several high functionaries of the state.

Ezbehs are hamlets or settlements isolated from neighboring villages, the inhabitants not being included in the census of the villages.

[b] An omdeh is the chief of a village; he is superior in authority to a sheik.

If the omdeh and the sheiks are absent, the said testimony shall be signed by the head officer of the district, or by one of the referees of the province or of the districts, or by an agent of police, on condition that they have presented direct evidence of the offense.

In the absence of these officials or of an agent of police, it will be sufficient in the prosecution if the testimony be countersigned, or simply signed, without a second signature being necessary, by an inspector of irrigation, a chief engineer, a director of public works, a superintendent of contracts, or an engineer appointed by the inspector of irrigation.

If the chief engineer should appoint a referee, or the inspector of irrigation an engineer, to take testimony in accordance with the provisions of this article, the governor should be informed immediately of the name of the person so appointed and the object of his appointment. The authority and duties of a person so appointed shall concern only a single case or a group of cases or a certain locality, in which the appointee must spend a fixed period, such as, for example, the breaking of regulations concerning rotation in the use of water from a certain canal or in a certain district during the period of rotation.

Article 2. The testimony shall be dated and must contain the following information:

(1) The full name, occupation, and residence of the accused.

(2) Proof of the act constituting the offense and of the time and of the place where committed.

All testimony shall be recorded, together with all the circumstances arising from the culpability of the accused, and shall be forwarded within twenty-four hours to the governor, accompanied by a statement fixing the amount of damages.

Article 3. A special register shall be kept at the office of the governor by an employee, who shall act as recorder for the commission. In this register he shall enter immediately—

(1) The date of the receipt of the report.
(2) The date of the taking of testimony.
(3) The full name, occupation, and residence of the accused.
(4) The character of the offense.

Article 4. Within twenty-four hours after receipt of the report the recorder shall summon the accused to appear before the commission. This summons, in duplicate, must contain—

(1) The full name, occupation, and residence of the accused.
(2) The character of the offense.
(3) Citation of the relevant provisions of the law.
(4) The day and hour when the accused shall appear.

At least three full days must intervene between the date of the summons and the date of appearance.

Article 5. An agent of the government shall be appointed to deliver a duplicate of the summons to the accused.

He shall make mention of such delivery at the bottom of both the original and duplicate summons, and shall affix the date of his signature.

The accused shall also sign or stamp the summons. In case of refusal or absence such fact shall be noted thereon, and the original summons shall be delivered to the sheik, who shall acknowledge receipt thereof.

Article 6. The recorder shall enter in the register provided for in article 3 the date of the summons and all proceedings to and including the final decision.

Article 7. The accused shall appear before the commission in person on the day and hour specified.

He may not in any event claim any irregularity whatever in the summons, for the fact of his appearance would nullify any such claim.

Article 8. Testimony duly signed shall be accepted as fact until proven to the contrary. The recorder shall read the testimony, together with any report which may accompany it.

Following this the accused will set forth the character of his defense, and, if the same court tries the case, he will then give his testimony.

The character of the defense and the depositions of testimony shall be briefly stated by the recorder in a report. The commission shall, before adjournment, give its decision, which must be justified by the facts.

They may require additional testimony if they believe it necessary. In such event they shall fix the day and hour when the new evidence shall be heard, which must be within fifteen days.

Article 9. If the accused does not appear at the first hearing, the commission shall ascertain if the provisions of articles 4 and 5 relating to the summons have been observed. If any irregularity be found, they shall order a new hearing, which shall take place within three days.

Article 10. If the summons has been properly issued, judgment by default will be given, and no appeal may be taken.

Article 11. Where an appeal is granted in accordance with the provisions of article 38 of the law on levees and canals, the accused, in making the appeal, must produce a receipt showing that he has deposited in the treasury of the province the amount of the fine and damages which have been imposed.

The appeal will not be received if it is not accompanied by the said receipt.

The appeal shall be transmitted within three days to the minister of the interior, with the decision and the other papers in the case.

Article 12. During the period of rotation in the summer—that is, the period during which rotations apply to machines and pumps—the commission shall assemble at least once a week. But if, within three days before the time of meeting, there has been no summons, and there is no case of emergency, the governor may give notice to the members of the commission that no meeting will be held during the said week.

Article 13. The governor shall be charged with the execution of the decisions, both of the commission and of the special committee of appeal.

Appendix II.

INSTALLATION OF MACHINES FOR ELEVATING WATER.

[Decree of March 8, 1881.]

Article 1. Any person, before establishing a machine for elevating water either for irrigation or drainage, whether the machine be stationary or movable, or propelled by steam or by a current of water, or by the wind, must receive permission from the public works ministry. This permit carries with it no right or title to the public or private lands traversed by the pipes, conduits, aqueducts, head gates, or occupied by the pumping plant, in any way whatsoever. The government remains neutral in all respects in all disputes between the people and the person receiving the permit and leaves to him all responsibility resulting from damages which may occur in the installation of the plant or in any other way.

Article 2. The erection of stationary elevating machines will be authorized only upon the banks of the Nile. At the same time the minister of public works may make exception and authorize the establishment of such machines upon certain canals. The minister is to be sole judge of the expediency of issuing a permit, and to him will be left all freedom regarding all agreements and conditions to which it will be subjected, as the case may demand.

Article 3. All machines for elevating water, whether stationary or movable, must be so installed as not to interfere with travel along the banks or the navigation of the canals, to respect all existing rights, and not add to the expense of maintenance of the canals or their banks, or to the defense of the country against inundation.

Article 4. In case the applicant fails to comply with the conditions and obligations imposed by the permit, it will be canceled without any claim on the government on account of such procedure as it may deem necessary to reimburse itself for such damage as may be done.

Article 5. A site for the installation of a machine at a certain place may not be changed except by the issuance of a new permit, which will be granted without requiring the payment of additional fees.

Article 6. The Government retains the right, whenever a public utility may require, such as the execution of public works dangerous to the dikes, irrigation works, etc., to cause any authorized pumping plant to be removed.

Article 7. The permit given for the installation of an elevating machine, whether stationary or movable, carries with it only the right for the applicants to install the plant in order to take water from a canal or the Nile. It carries with it no assurance from the government of a supply of water for the machine, nor does it insure a passage for the water elevated by the machine. The applicants must come to an understanding with their associates, or the people whose land they must cross, without interfering with the government in any way. In order to conduct water over waste or other land of the government, the applicant must secure a special permit. It is prohibited to make ditches to bring the water along the banks of the canals or of the Nile, as well as upon the roads or slopes of the banks.

Article 8. The ditches or conduits for carrying the water from the machines to the land will be constructed in such a manner and be of such a kind as not to interfere with travel, the flow of water, or with irrigation, according to the rights reserved by the people to whom the applicant alone remains responsible. The government will allow such construction as it deems safe and necessary for permitting the passage of conduits under dikes and roads and under or above canals.

Article 9. For the general good, in case of exceptional low water, or when the flow of the canal becomes greatly inferior to the needs of the agriculture which it serves, the public works ministry, in accordance with a measure generally applicable to canals or a single reach of a canal, may order the immediate closing of the elevating machine, or reduce the capacity of the same in accordance with its location, the relative importance of the machine, the area of the land which it irrigates, and in no case will the government incur any responsibility for damage caused to agriculture.

Article 10. Under the provisions of article 7, the ministry of public works is, under certain conditions, authorized to permit the use of a public Nili canal for carrying water from the elevating machine to the land to be irrigated, under the following reservations:

(1) Such permission will be given only during the season of low water and ends when the water of the Nile will flow freely in the canal.

(2) Permission will be given only when the proprietors of the land who use the Nili canal have given their general consent.

(3) If it is found necessary to construct dams to maintain the level of the water along a Nili canal, these must be of earth and they must be built by the owner of the machine, in case of necessity, by the government, but at the expense, risk, and peril of the proprietor, before the water of the Nile can flow freely into the canal.

(4) Finally, the owner of the machine is alone responsible to the people for all damage occasioned by the breaking of dams, percolation, and delay in building the dams at the time the supply of water is available.

Article 11. Any person who, contrary to the foregoing provisions of this decree, may have installed a stationary or a movable machine without receiving a permit, must, before August 31, 1881, apply for a permit under the conditions prescribed by this decree and its regulations. Any person furnished with a permit prior to this decree must, before the same date, secure a new permit under the same conditions, but he will not be compelled to pay additional fees.

Article 12. After August 31, 1881, the operation of all machines established contrary to the provisions of article 11 preceding, will be stopped.

Article 13. The owners of elevating machines are responsible for accidents and damage which may be occasioned by the machines. The government reserves the right to exercise, in the interest of the public, a supervision of the working of the machines without removing from the proprietors the responsibilities which may be incumbent upon them.

Article 14. Regulations for carrying this decree into effect and for the protection of such interests as are affected thereby will be prepared by the ministry of public works.

[Decree of the minister of public works, April 6, 1881.]

Article 1. All applications for permits to establish a movable engine for elevating water should be made upon stamped paper and be addressed to the governor or to the province in the circle where the machine is to be established. The application should contain the following information:

(1) The kind of engine and pump, together with its capacity and its principal dimensions.

(2) The location of the place where it is proposed to establish it, together with its plan.

(3) Whether the machine is to be established for irrigation or drainage purposes.

(4) The full names, professions, nationalities, and residences of the owners of the land to be irrigated or drained.

(5) The period for which the permit is required.

Article 2. The application is recorded by the province or in the governor's office upon a special register. It receives a number in sequence after the payment of fixed fees of 100 piasters ($4.93) for each machine for the expense of the examination. It is then transmitted for examination to the chief engineer of the circle in which the governor's office is found.

Article 3. If the chief engineer of the circle approves the project he draws up in due form and signs the permit, which should contain:

(1) The agreement under which the applicant must conform to the present decree and all future laws and regulations.

(2) A description of the site upon which the machine is to be erected, with drawings to show the same.

(3) The special features of the machine, especially those relative to the passageway under the bank of the canal, the main sluiceway, the manner of closing the same, etc.

The permit being issued only in view of the necessities of the public service, it allows all facts to become public, so that anyone can object to the occupation of the land by the machine or legally oppose its establishment.

Article 4. The permit is sent by the engineer of the circle to the province or to the governor, is signed by the latter, and forwarded to the applicant in order to obtain his signature on the margin of the duplicate of the authorization recorded upon the register upon the payment of 50 piasters ($2.47) per horsepower. This tax, however, shall never be less than 500 piasters ($24.65).

Article 5. All applications for erecting stationary elevating machines should be addressed upon stamped paper to the ministry of public works, which immediately approves applications if it thinks best. The application should always be accompanied by papers describing the installation of the machine and the main head works, and if plans of the machine itself are not given a full description should be furnished instead.

Article 6. Permits for the establishment of stationary machines for elevating water are subject to the same fees for examination and authorization as for movable machines. These fees are paid directly into the treasury of the public works ministry.

ARTICLE 7. In no case can the applicant proceed with the installation without first receiving a permit.

ARTICLE 8. No machine can be established upon a main sluiceway, bridge, dam, or other work of a public nature, or near these works, the distance away being determined in each case by the public works ministry.

ARTICLE 9. The permit provided for in article 5 of the decree of March 8, 1881, shall be given by the chief engineer of the district, who will notify the province or the government of the removal which he shall have authorized.

ARTICLE 10. The removal of machines provided for by article 6 of the decree above referred to shall be ordered by the public works ministry only. It shall be made at the expense of the applicant.

ARTICLE 11. All previous acts and parts of acts conflicting with this decree are hereby repealed.

APPENDIX III.

DRAINAGE OF SWAMPS AND MARSHES.

[Act approved by the Council of Ministers, February 21, 1894.]

ARTICLE 1. Insalubrious swamps and marshes belonging to the government may be ceded to individuals, who must, after coming into possession of such lands, make embankments and perform such other work as is hereinafter provided.

ARTICLE 2. Applications for cession must be addressed to the province or to the seat of government on stamped paper of 30 milliemes (about 15 cents), and contain the following information:

(1) The location of the swamp or marsh.

(2) The town or village where it is situated.

(3) Its approximate area and its boundaries.

(4) The place where the applicant proposes to secure earth for building the embankment.

(5) The time when the work will begin.

(6) The time within which the work will be finished. This time can not in any case exceed 2 years.

ARTICLE 3. The governor will communicate the application to the inspector of irrigation for his advice and in order to fix the location of the embankment to keep back the water.

Where such swamp or marsh is found within the limits of a city subject to government regulations, the advice of the local government officials must be obtained.

ARTICLE 4. The governor will thereupon transmit the application and the papers accompanying it, with his recommendations, to the minister of finance, who will give his decision.

ARTICLE 5. If the application be approved, the governor will proceed to have the boundary of the swamp or marsh fixed by the engineer of the province or of the government, and will have the applicant sign an agreement containing the following stipulations:

(1) To begin the embankment work within the time specified.

(2) To execute at least a quarter of the work within the first quarter of the time prescribed for the completion of the whole.

(3) To complete the embankment in the prescribed manner within the time agreed upon.

(4) To take earth from no place other than that designated.

If the agreement is not adhered to, the applicant will be deprived of all right or title in or to the swamp or marsh, without any compensation for expense incurred in drainage or in building such part of the embankment as may have been completed.

Article 6. The governor will then furnish an authorization in writing, giving the location, boundaries, and area of the swamp or marsh and all the conditions of the agreement.

Article 7. If the applicant has not commenced work within the time specified, or if, having commenced in due time, he has not completed a fourth of the work within the period specified in paragraph 2 of article 5, the authorization will become null and void, and the government may dispose of the swamp or marsh as it deems best.

Article 8. Whenever the work is commenced and completed without delay in accordance with the above provisions, at the expiration of the period fixed for its accomplishment the governor shall visit the swamp or marsh with the engineer of the province or of the seat of government, who will determine by testimony whether or not the embankment has been fully completed in the manner prescribed.

The applicant shall be informed of the day and hour of this visit at least three days prior thereto, in order that he may be present if he so desires.

Article 9. If it be shown by the testimony of the engineer that the embankment has not been completed within the period fixed, the governor shall take possession of the land of the swamp or marsh, which will in all cases be considered the property of the state, and the applicant may not make any claim for damages under the terms of his agreement.

Article 10. In such cases as are provided for in the preceding article and in article 7 the applicant may appeal from the decision of the governor to the minister of finance, whose decision shall be final.

The appeal must be presented within fifteen days after the decision has been signed in due form.

Article 11. If, on the contrary, the testimony of the engineer establishes the fact that the embankment has been properly constructed, the governor shall so inform the minister of finance, who will order a title deed to the property to be issued in the name of the applicant, and the land of the swamp or marsh thus acquired will be exempt from taxation for ten years, beginning with the expiration of the time for completing the embankment.

Article 12. The provisions of this act are applicable only to swamps and marshes located within 1,000 meters (3,281 feet) of a city, town, or village.

[Decree of April 26, 1900.]

Article 1. Excavating within or to the north of cities, towns, and villages, whether for the manufacture of brick or for any other purpose whatsoever which may have a tendency to form a body of water, is prohibited within 3,000 meters (9,843 feet) of any dwelling.

Such excavations are also prohibited to the south, east, and west upon lands situated within 1,000 meters (3,281 feet) of any dwelling.

These prohibitions apply equally to excavations or embankments of earth having for their purpose the extension in area or deepening of bodies of water already existing.

Article 2. All infractions of the preceding article will be subject to a fine of from 50 to 100 P. T. ($2.47 to $4.93). Not only are those who actually perform such work held liable, but also the owners, administrators, superintendents, or any other persons who may have ordered or instigated the work of excavation or embankment.

Article 3. The offenders will be, in addition, compelled to restore the ground to the level it had before the excavations were made, and if after a month from the date of the sentence such work has not been completed, the governor may cause the same to be done at the expense of the offenders.

Article 4. Such expense will be recovered in accordance with the provisions of the decree of March 25, 1880.

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LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON IRRIGATION—Continued.

Bul. 119. Report of Irrigation Investigations for 1901 under the direction of Elwood Mead, chief. Pp. 401. Price, 50 cents.

Bul. 124. Report of Irrigation Investigations in Utah, under the direction of Elwood Mead, chief, assisted by R. P. Teele, A. P. Stover, A. F. Doremus, J. D. Stannard, Frank Adams, and G. L. Swendsen. Pp. 330. Price, $1.10.

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